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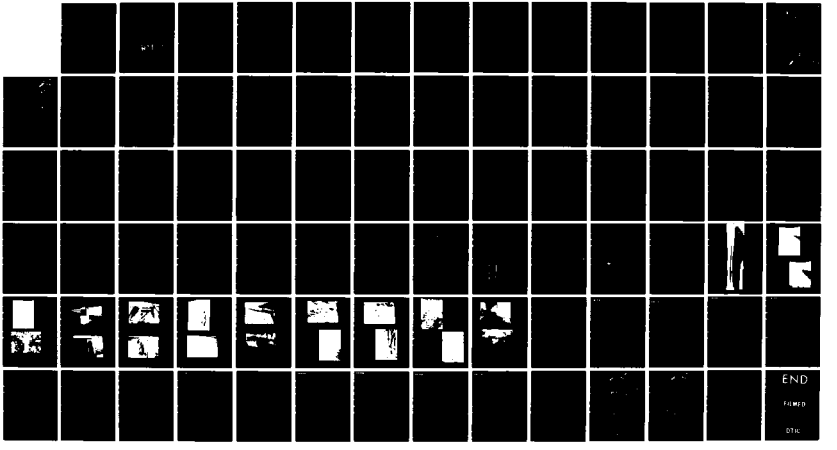

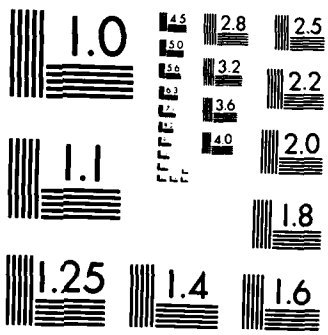

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AD-A156 110

CONNECTICUT RIVER BASIN

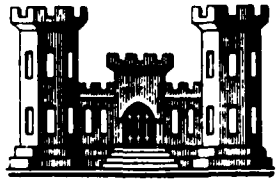
HANOVER, NEW HAMPSHIRE

LOWER RESERVOIR DAM

NH 00048

NHWRB NO. 108.05

PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM



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19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

DAMS, INSPECTION, DAM SAFETY,

Connecticut River Basin
Hanover New Hampshire
Camp Brook

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

The dam is an earthen structure with an overall length of 1023 ft. and a maximum height of 33 ft. The dam is considered to be in poor condition. Seepage was noted both under the stone arch bridge and at the joint of the spillway weir and spillway apron slab. It is small in size with a hazard potential of significant.

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LOWER RESERVOIR DAM

NH 00048

NHWRB 108.05

CONNECTICUT RIVER BASIN
HANOVER, NEW HAMPSHIRE

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PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

NATIONAL DAM INSPECTION PROGRAM
PHASE I - INSPECTION REPORT
BRIEF ASSESSMENT

Identification No.: 00048

Name of Dam: Lower Reservoir Dam

Town: Hanover

County and State: Grafton, New Hampshire

Stream: Camp Brook

Date of Inspection: October 26, 1979

Lower Reservoir Dam is an earthen embankment structure with an overall length of 1,023 feet. Maximum height as measured from the dam crest to the streambed is 33 feet. Top width is 9 feet. The upstream and downstream embankments are on a 2 horizontal to 1 vertical slope. The spillway section has a 33 foot long concrete weir crest and concrete training walls. Outlet works consist of three intake pipes; a 20 inch diameter high level, a 20 inch diameter low level and a 16 inch diameter waste pipe. All intakes are controlled with gate valves of the same size as the respective pipe diameters. All controls are in a gate house tower which is located about 400 feet from the left abutment. The dam was originally constructed in 1893, and has been reconstructed twice. The last reconstruction was in 1954. The impoundment is used for water supply. There is a set of drawings available, however, no design calculations or construction data were revealed.

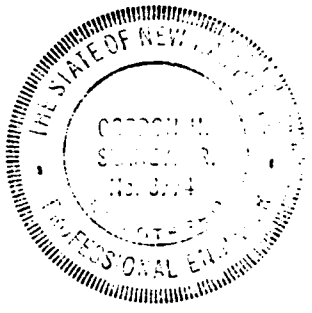
The visual inspection revealed that the dam is in poor condition. The visual inspection revealed cracking on the left training wall of the spillway, the unmortared stone portion of the right training wall and in the stone arch bridge immediately downstream of the spillway. Seepage was noted both under the stone arch bridge and at the joint of the spillway weir and spillway apron slab.

Based on a maximum storage of 823 acre-feet and a maximum height of 33 feet, Lower Reservoir Dam falls within the small size classification. The dam's hazard classification has been established to be significant based on potential flooding of a camp ground and overtopping of a downstream dam by the breach flood wave. Based on the small size of the dam and its significant hazard classification and in accordance with Corps of Engineers Guidelines, the test flood inflow should be of a

magnitude ranging from a 100 year frequency flood to 1/2 the Probable Maximum Flood (PMF). One half the PMF was used for the test flood inflow, which is 2,325 cfs. The routed test flood outflow of 1,860 cfs overtops the dam by approximately 0.5 feet. With the water surface at the top of dam the spillway capacity without flashboards is approximately 700 cfs (about 38 percent of the routed test flood outflow).

It is recommended that the owner engage a qualified, registered engineer to (1) thoroughly investigate the spillway and the arch bridge over the spillway with the intent of designing remedial measures, (2) design slope protection for the crest and downstream slope of the dam adjacent to the spillway section and (3) devise a means for removal of flashboards during high water. Remedial measures include the development of a downstream warning system and clearing of the spillway discharge channel of overhanging trees.

The recommendations and remedial measures are described in Section 7 and should be addressed within 1 year after receipt of this Phase I - Inspection Report by the owner.



Gordon H. Slaney, Jr., P.E.
Project Engineer

HOWARD NEEDLES TAMMEN & BERGENDOFF
Boston, Massachusetts

This Phase I Inspection Report on Dam has been reviewed by the undersigned Review Board members. In our opinion, the reported findings, conclusions, and recommendations are consistent with the Recommended Guidelines for Safety Inspection of Dams, and with good engineering judgment and practice, and is hereby submitted for approval.

CHARLES G. TIERSCH, Chairman
Chief, Foundation and Materials Branch
Engineering Division

FRED J. RAVENS, Jr., Member
Chief, Design Branch
Engineering Division

SAUL COOPER, Member
Chief, Water Control Branch
Engineering Division

APPROVAL RECOMMENDED:

JOE B. FRYAR
Chief, Engineering Division

THIS SHEET TO BE FURNISHED BY THE CORPS OF ENGINEERS

PREFACE

This report is prepared under guidance contained in the Recommended Guidelines for Safety Inspection of Dams, for Phase I Investigations. Copies of these guidelines may be obtained from the Office of Chief of Engineers, Washington, D.C. 20314. The purpose of a Phase I Investigation is to identify expeditiously those dams which may pose hazards to human life or property. The assessment of the general condition of the dam is based upon available data and visual inspections. Detailed investigations and analyses involving topographic mapping, subsurface investigations, testing and detailed computational evaluations are beyond the scope of a Phase I Investigation; however, the investigation is intended to identify any need for such studies.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with data available to the inspection team. In cases where the reservoir was lowered or drained prior to inspection, such action, while improving the stability and safety of the dam, removes the normal load on the structure and may obscure certain conditions which might be otherwise detectable if inspected under the normal operating environment of the structure.

It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through continued care and inspection can there be any chance that unsafe conditions be detected.

Phase I inspections are not intended to provide detailed hydrologic and hydraulic analyses. In accordance with the established Guidelines, the Spillway Test Flood is based on the estimated "Probable Maximum Flood" for the region (greatest reasonably possible storm runoff), or fractions thereof. Because of the magnitude and rarity of such a storm event, a finding that a spillway will not pass the test flood should not be interpreted as necessarily posing a highly inadequate condition. The test flood provides a measure of relative spillway capacity and serves as an aide in determining the need for more detailed hydrologic and hydraulic studies, considering the size of the dam, its general condition and the downstream damage potential.

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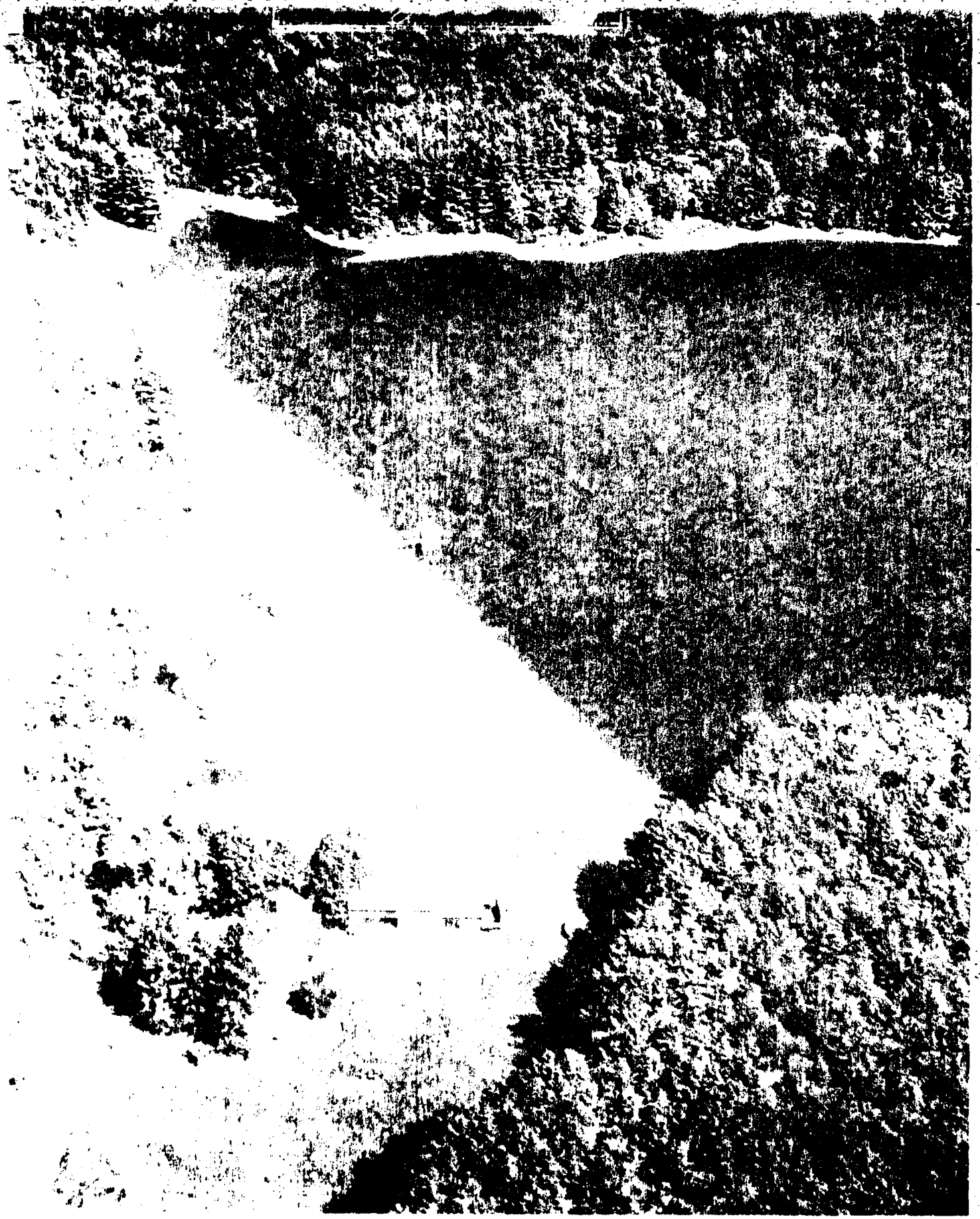


Lower Reservoir Dam - Overview from above left abutment

SECTION 5
HYDROLOGY AND HYDRAULIC ANALYSIS

5.1 Evaluation of Features

a. General. Lower Reservoir Dam is an earthen structure with an overall length of 1,023 feet and a maximum height of 33 feet. At the crest the dam is 9 feet wide. Upstream and downstream faces are a 2 horizontal to 1 vertical slope. The upstream face has riprap protection and the crest and downstream slope have a vegetative cover. The spillway crest has a length of 33 feet and is 3.5 feet below the crest of the dam. The outlet works consist of three pipes; a 20 inch diameter high level intake with a 20 inch gate valve, 20 inch diameter low level intake with a 20 inch gate valve and a 16 inch diameter waste pipe with a 16 inch diameter gate valve.

The impoundment is used for water supply by the Hanover Water Works Company. The dam is classified as small in size with a height of 33 feet and a maximum storage of 823 acre-feet.

b. Design Data. The only engineering data available is a set of three drawings showing the old dam and the modifications made in 1954.

c. Experience Data. There are no records of maximum discharge at the site. However, it was reported that in June 1973 the water was 5 inches above the flashboards which would correspond to a discharge of 31 cfs.

d. Visual Observations. No evidence of damage to any portion of the project from overtopping was visible at the time of inspection.

e. Test Flood Analysis. No detailed design and operational information are available for this dam. The hydrologic evaluation was performed using information gathered by field investigation, watershed characteristics, and Probable Maximum Flood (PMF) curves prepared by the Corps of Engineers. In accordance with Corps of Engineer Guidelines the significant hazard classification and small size classification of this dam warrants a test flood magnitude ranging from a 100-year frequency flood to 1/2 the PMF. A test flood equal to 1/2 the PMF was used. A test flood inflow of 2,325 cfs is based on a watershed 1.86 square miles in mountainous terrain. The test

SECTION 4
OPERATIONAL PROCEDURES

4.1 Procedure

Lower Reservoir is used exclusively for water supply. The reservoir receives releases from Upper Reservoir and Reservor No. 3 to maintain a working level. Reservoir No. 3 is located in another watershed. There is a continual supply to the water destribution system as the main service area is fed by gravity. The waste pipe is usually closed. The flashboards on the spillway are removed from December to April of each year.

4.2 Maintenance of Dam

The dam is inspected on a daily basis by personnel of the Hanover Water Works Company. Vegetation on the crest and downstream slope is cut at least once a year. Repairs are made when required.

4.3 Maintenance of Operating Facilities

The outlet works gates are operated once a year. The facilities are repaired as required.

4.4 Description of Warning Systems

There are no warning systems in effect for this facility.

4.5 Evaluation

The current operational and maintenance procedures appear to be adequate to insure that normal problems encountered can be remedied within a reasonable period of time. However, the owner should arrange to have a technical inspection made on an annual basis.

The owner should establish a written operational procedure as well as establishing a warning system to follow in the event of emergency conditions.

(f) The spillway channel downstream has many trees along the banks and a fallen tree in the channel.

(g) There is no means of removing the flashboards during high water without exposing personel to hazardous conditions.

The flashboards on the spillway crest were in good condition. However, there is no means of removing the flashboards during high water without exposing personel to hazardous conditions.

The right wingwall at the approach to the spillway is cracked through the entire wall thickness and reinforcement is visible as shown in Photo No. 12.

The outlet works consist of intake structures, piping, a gate house and outlet channel. The intake structures could not be inspected as they were underwater at the time of inspection as were the gate valves in the gate house. The gate house is shown in Photo No. 6, and can be reached by a wood deck walkway supported by steel beams which is in good condition. The operating mechanisms are manually operated and appeared to be in good condition. Overall the gate house was in good condition. The waste pipe discharges to a 5 foot bottom width earth channel which is the original streambed.

d. Reservoir Area. The overall reservoir can be seen in Photo No. 1. The banks are free of debris, even though the area surrounding the reservoir is heavily wooded. There are no islands in the reservoir.

e. Downstream Channel. The spillway below the downstream toe of the embankment is shown in Photo No. 19. The discharge channel has numerous trees along its bank which should be removed, in addition to a fallen tree in the channel.

3.2 Evaluation

Visual examination indicates that the dam is in poor condition. Visual examination revealed the following:

(a) Caving and erosion of the embankment immediately behind the masonry section of the right training wall.

(b) The original stone masonry portions of the spillway still in place have undergond significant movement and the stone mortar has cracked.

(c) A stone arch bridge at the downstream end of the spillway has undergone movement and cracked through the arch.

(d) Leaks were noted at the junction of the toe of the spillway weir and spillway apron slab and at the floor of the channel under the stone arch bridge.

(e) Reinforcing steel has been exposed through a crack in the upstream right wingwall of the spillway.

About 1971 there was a local overtopping of the embankment adjacent to the left training wall of the spillway, due to an ice jam. A 5 to 6 foot deep channel was eroded in the downstream slope from the crest to the toe of the embankment. This erosion has been repaired.

There is caving and erosion of the embankment immediately behind the masonry section of the right training wall of the spillway. This erosion is shown in Photo No. 5. This erosion channel is 4 feet deep, about 2 feet wide, and extends for a distance of about 5 feet along the training wall. The erosion has been caused by surface water runoff. No sign of seepage through the embankment was observed inside the eroded void.

c. Appurtenant Structures. Visual inspections of the spillway structure, spillway channel, control gate house and outlet works did not disclose any immediate unsafe conditions. However, inspection of the spillway structure indicted that the training walls have experienced considerable deterioration in the form of concrete cracks. In addition, the stone masonry portion of the old spillway has undergone significant movements.

The existing spillway is a modification of an original spillway structure. A new weir, floor slab, and training walls constructed of concrete were built when the dam was raised. That portion of the spillway at the downstream toe was not rebuilt and is constructed of mortared stone. This original section of the spillway has undergone significant movements and the mortared stone has been cracked and displaced. A stone arch bridge passes over the downstream end of the spillway, as shown in Photo No. 13. The left abutment of this arch bridge has undergone several inches of movement resulting in a crack through the arch. A section of the crack which passes through the entire arch is shown in Photo No. 15.

Photo No. 14 shows a crack in the masonry training wall on the right side of the spillway. This crack is located immediately in front of the area of erosion discussed earlier.

The masonry training wall immediately downstream of the left abutment of the arch has been severely damaged and displaced, as shown in Photo Nos. 16 and 17. Note in Photo No. 17 that the stone wall is leaning against the tree.

There is a leak in the floor of the arch bridge 65 feet downstream of the spillway weir. This leak is shown in Photo No. 18. The water emerging from the leak is clear.

Seepage through joints shown in Photo No. 11, indicate a leaky joint at the spillway apron slab and spillway weir.

SECTION 3
VISUAL INSPECTION

3.1 Findings

a. General. The field inspection of Lower Reservoir Dam was made on October 26, 1979. The inspection team consisted of personnel from Howard, Needles, Tammen & Bergendoff and Geotechnical Engineers, Inc. A representative of the owner was also present during the inspection. Inspection checklists, completed during the inspection, are included in Appendix A. At the time of inspection, the water level was approximately 2.8 feet below the spillway crest. The upstream face of the dam could only be inspected above this level.

b. Dam. Visual inspection of the embankment portion of the dam indicated that it is in good condition.

The dam consists of an earth embankment about 1,023 feet long and 33 feet high.

There is a concrete spillway passing through the embankment near the right abutment.

Visual inspection revealed that the dam is in good condition with exception of the area immediately adjacent to the spillway structure and the downstream portion of the spillway channel within and just downstream of the embankment section. Because of this the dam is assessed as being in poor condition.

Upstream Slope

The upstream slope is inclined at 2 horizontal:1 vertical. Photo No. 3 shows the upstream slope. The reservoir level was below normal high water elevation permitting inspection of the riprap slope protection which was in good condition.

Crest

The crest of the embankment is 9 feet wide and, as shown in Photo No. 2, is well grassed. No misalignment of the crest was observed.

Downstream Slope

The downstream slope is inclined at 2 horizontal to 1 vertical. Photo No. 4 shows the downstream slope which in general is in good condition.

SECTION 2
ENGINEERING DATA

2.1 Design

Plans of the 1954 reconstruction of Lower Reservoir Dam are on file with the New Hampshire Water Resources Board. These plans also show the dam existing at that time. Design was done by Weston & Sampson, Boston, Massachusetts. No specifications or design calculations were made available. There is no record of any modifications to the dam since the 1954 reconstruction.

2.2 Construction

No construction records are available for use in evaluating the dam.

2.3 Operation

No engineering operational data were disclosed.

2.4 Evaluation

a. Availability. Information available consists of a set of 3 plan sheets and an inspection report by the New Hampshire Water Resources Board. The above data is available at the Department's offices in Concord, New Hampshire.

b. Adequacy. The lack of in-depth engineering data did not allow for a definitive review. Therefore, the adequacy of this dam could not be assessed from the standpoint of reviewing design and construction data, but is based primarily on visual inspection, past performance history and sound engineering judgment.

c. Validity. The field inspection indicted that the external features of Lower Reservoir Dam substantially agree with those shown on the available plans.

(8) Cutoff - unknown

(9) Grout Curtain - unknown

(10) Other - unknown

h. Diversion and Regulating Tunnel

See Section j below.

i. Spillway

(1) Type - concrete weir

(2) Length of Weir - 33 feet

(3) Crest Elevation - 708.0

(4) Controls - flashboards 1.0 feet high to elevation 709.0

(5) Upstream Channel - none

(6) Downstream Channel - about 8 feet downstream of the spillway apron slab the outlet channel passes through a 9 foot wide, 5.3 foot high arch opening for a roadway bridge. Downstream of the bridge there is a earth channel with an eight foot bottom width and 1 horizontal to 1 vertical side slopes. The spillway outlet channel joins the natural stream channel about 700 feet downstream of the dam.

j. Regulating Outlets. The 16 inch waste pipe centerline is set at elevation 679.67. The pipe is gated with a 16 inch gate valve at the gate house and discharges to the natural stream channel.

(8) Top Dam - 711.5

(9) Test Flood Surcharge - 712.0

d. Reservoir (miles)

(1) Length of Maximum Pool - 0.41

(2) Length of Normal Pool - 0.40

(3) Length of Flood Control Pool - N/A

e. Storage (gross acre-feet)

(1) Normal Pool - 659

(2) Flood Control Pool - N/A

(3) Spillway Crest Pool - 659

(4) Top of Dam - 823

f. Reservoir Surface (acres)

(1) Normal Pool - 47

(2) Flood Control Pool - N/A

(3) Spillway Crest - 47

(4) Test Flood Pool - 47

(5) Top Dam - 47

g. Dam

(1) Type - earth

(2) Length - 1,023 feet

(3) Height - 33 feet

(4) Top Width - 9 feet

(5) Side Slopes - upstream and downstream 2 horizontal to 1 vertical

(6) Zoning - unknown

(7) Impervious core - unknown

miles. Reservoir No. 3 is located in a different watershed. Maximum elevation in the basin is about 1,280 feet NGVD. There are five peaks above elevation 1,000. The average reservoir level would be about elevation 707.0.

The reservoir is about 47 acres in extent. There are no overhanging trees or dead wood along the shoreline, however, just beyond the reservoir the area is heavily wooded.

b. Discharge at Dam Site. The outlet works consist of three pipes. There are two water supply intakes; a 20 inch diameter high level intake at elevation 694.33, and a 20 inch diameter low level intake at elevation 683.83. Each intake is gated separately with 20 inch diameter gate valves. There is a 16 inch diameter wasteline at elevation 679.67 which is gated with a 16 inch gate valve. With the water surface at the spillway crest, maximum capacity of the waste pipe would be about 30 cfs.

(1) There are no records of maximum discharge at the site. However, it was reported that in June 1973, the water level was 5 inches over the flashboards which would correspond to a discharge of about 31 cfs.

(2) The spillway capacity with the water surface the top of dam, elevation 711.5, would be about 700 cfs without the flashboards and 450 cfs with the flashboards.

(3) The spillway capacity with the water surface at the test flood elevation of 712.0 would be about 860 cfs.

(4) The total project discharge at the test flood elevation of 712.0 is approximately 1,860 cfs.

c. Elevation (feet above NGVD)

(1) Streambed at centerline of dam - 678.5

(2) Maximum tailwater - unknown

(3) Upstream invert of outlet works - High level - 694.33
Low level - 683.83
Waste pipe - 679.67

(4) Normal pool - 708.0

(5) Full flood control pool - N/A

(6) Spillway crest (permanent spillway) - 708.0

(7) Design surcharge - N/A

d. Hazard Classification. The potential for damage posed by this dam is classified as significant. Failure of the dam with the water level at the top of dam would result in a flood wave about 20 feet high in the reach extending from the dam to Storrs Pond located 5,000 feet downstream. Along this reach there is a road parallel to the stream and about 4 feet above streambed which would be inundated. About 3,000 feet downstream of the dam the road crosses the stream over a 8 foot by 8 foot waterway opening. The road surface is about 12 feet above the streambed. At the upstream end of Storrs Pond there is a camp ground with recreation facilities including tennis courts. This area is about 6 feet above the streambed. Storrs Pond Dam, located 3,000 feet downstream of the head of the pond, would be overtopped.

e. Ownership. This dam is owned by the Hanover Water Works Company, P.O. Box 1006, Hanover, New Hampshire 03755.

f. Operator. This dam is operated by the Hanover Water Works Company, Mr. Carl Brink, Superintendent, P.O. Box 1006, Hanover, New Hampshire, Telephone No. 603-643-3506.

g. Purpose of Dam. The impoundment is used exclusively for water supply by the Hanover Water Works Company. Lower Reservoir receives outflow from two other reservoirs, Upper Reservoir and Reservoir No. 3. The reservoir supplies to the water destribution system by gravity.

h. Design and Construction History. Original construction of a dam at this site was in 1893. Since that time the dam has been reconstructed twice. There was no information available regarding the original dam and the first date of reconstruction was in 1915. In about 1954, the dam was raised about 5 feet. In addition, the gate house structure and spillway crest were raised and the spillway training walls and apron rebuilt. Since 1954 there have been no modifictions to the dam.

i. Normal Operating Procedures. The reservoir level is determined according to water demand and runoff. The Lower Reservoir storage is also augmented by releases from Upper Reservoir and Reservoir No. 3. Water is transferred so as to maintain a minimum level in Lower Reservoir. The flashboards on the spillway crest are removed from December to April each year.

1.3 Pertinent Data

a. Drainage Area. The area tributary to Lower Reservoir consists of 1.86 square miles of mountainous wooded terrain. The watershed is owned by the Hanover Water Works Company and there is no development. Upper Reservoir is located 0.7 mile upstream of the dam and has a tributary area of 0.83 square

b. Description of Dam and Appurtenances. Lower Reservoir Dam is an earthen embankment structure with an overall length of 1,023 feet. The dam has a maximum height of 33 feet as measured from the dam crest to the streambed. The crest of the dam is 9 feet wide. The upstream face is on a 2 horizontal to 1 vertical slope as is the downstream embankment. The present dam is constructed on an old dam. The present crest is 5 feet above the old crest. The raised portion of the dam is placed against the downstream face and on the crest of the old dam and is of unidentified material. A gravel blanket 3.6 feet thick was placed on the lower half of the downstream face. A stone drain was placed at the downstream toe of slope. The crest and downstream embankment are covered with loam and grass. The upstream face is protected with riprap from about mid-height to the crest.

Appurtenant structures consist of a spillway and discharge channel, outlet works, and a gate house structure. The spillway has a 33 foot long concrete weir crest. Flashboards 1.0 feet high are on the spillway crest. Concrete training walls flair out on the upstream side to a 40 foot width, and converge downstream of the weir to a width of about 16 feet. The spillway apron slab is constructed of concrete and extends to about 40 feet downstream of the weir crest.

Outlet works consist of three intake pipes with valves located in the gate house. The gate house is located about 400 feet from the left abutment. Two intake structures are located in the reservoir: one is about 40 feet from the gate house and is the pond drain, connected to the gate house via a 16 inch diameter cast iron pipe. The 20 inch low level intake is located 20 feet out into the reservoir and is connected via a 20 inch diameter tile pipe. The high level intake is located at the gate house. Each line is valved separately with the respective sized gate valves. The gate house is reached via a plank deck catwalk supported by steel beams. The pond drain discharges to a stream channel, and the water supply intakes discharge to two lines 14 and 16 inches in diameter. Downstream of the gate house, at the toe of slope there are two buildings, one contains metering and chlorination facilities and the other is for storage.

Figures 1 and 2 located in Appendix B, show a plan of the dam and its appurtenant structures. Photographs of each structure are shown in Appendix C.

c. Size Classification. Small (hydraulic height 33 feet, storage 823 acre-feet) classification based on the hydraulic height being less than 40 feet and the storage being less than 1,000 acre-feet as given in Recommended Guidelines for Safety Inspection of Dams.

NATIONAL DAM INSPECTION PROGRAM
PHASE I INSPECTION REPORT
LOWER RESERVOIR DAM

SECTION 1
PROJECT INFORMATION

1.1 General

a. Authority. Public Law 92-367, August 8, 1972, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a National Program of Dam Inspection throughout the United States. The New England Division of the Corps of Engineers has been assigned the responsibility of supervising the inspection of dams within the New England Region. Howard, Needles, Tammen & Bergendoff has been retained by the New England Division to inspect and report on selected dams in the State of New Hampshire. Authorization and notice to proceed were issued to Howard, Needles, Tammen & Bergendoff under a letter of August 24, 1979 from William E. Hodgson, Jr., Colonel, Corps of Engineers. Contract No. DACW33-79-C-0060 has been assigned by the Corps of Engineers for this work.

b. Purpose

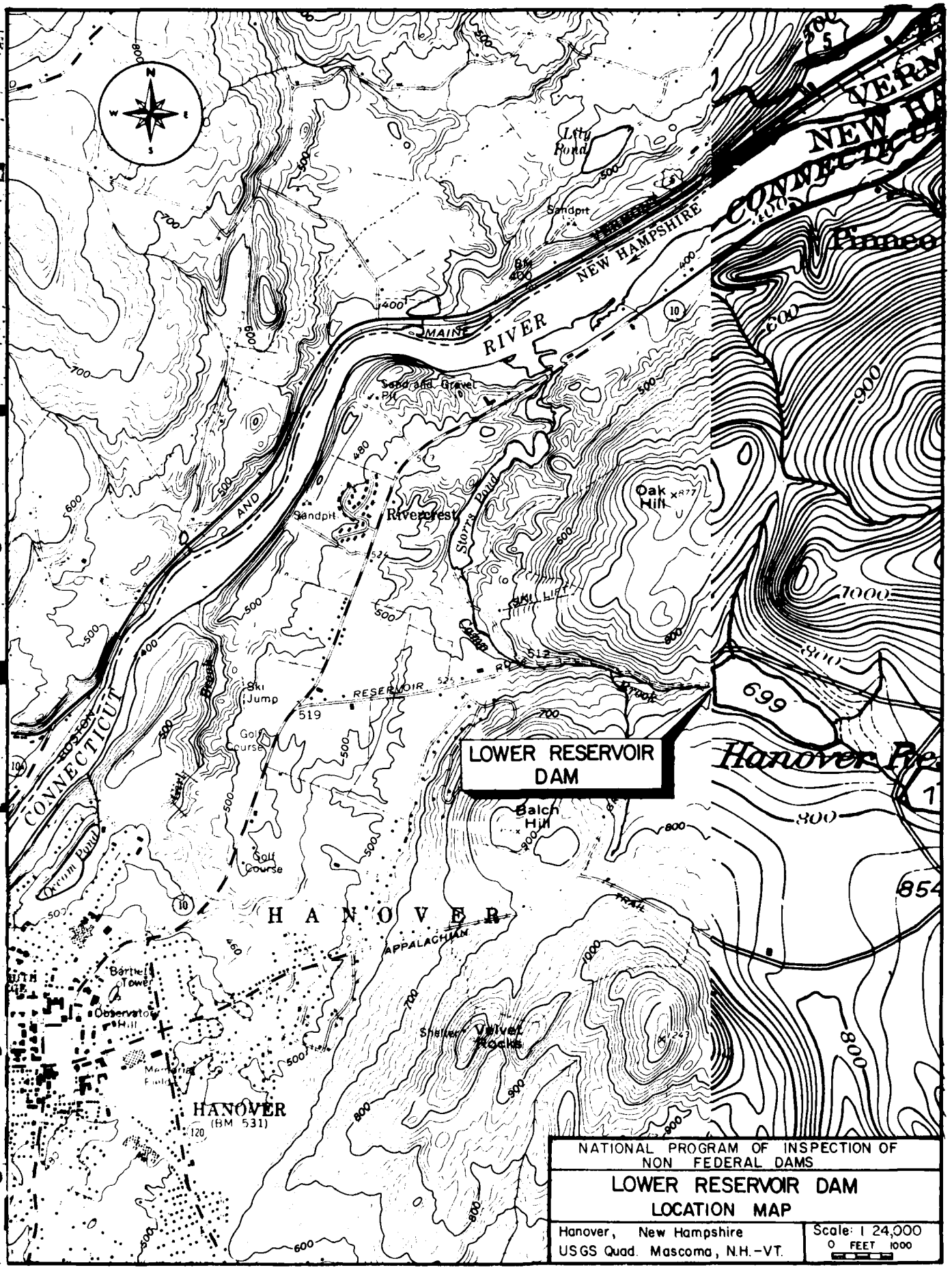
(1) To perform technical inspection and evaluation of non-Federal dams to identify conditions which threaten the public safety and thus permit correction in a timely manner by non-Federal interests.

(2) To encourage and prepare the states to initiate quickly effective dam safety programs for non-Federal dams.

(3) To update, verify and complete the National Inventory of Dams.

1.2 Description of Project

a. Location. Lower Reservoir Dam is located on Camp Brook approximately 1.7 miles upstream of the Connecticut River in the Town of Hanover, New Hampshire. The dam is shown on U.S.G.S. Quadrangle Mascoma, New Hampshire-Vermont, with approximate coordinates N43°43'09", E72°14'59", Grafton County, New Hampshire. The location of Lower Reservoir Dam is shown on the preceding page.



NATIONAL PROGRAM OF INSPECTION OF NON FEDERAL DAMS

LOWER RESERVOIR DAM
LOCATION MAP

Hanover, New Hampshire
USGS Quad. Mascoma, N.H.-VT.

Scale: 1 24,000
0 FEET 1000

flood was routed through upper Reservoir which is located .7 mile upstream of Lower Reservoir Dam with a drainage area of 0.83 square miles. The routed outflow was added to the drainage area runoff directly tributary to Lower Reservoir.

The routed test flood outflow was determined in accordance with Corps of Engineers Guidance for Estimating Effect of Surcharge Storage on Maximum Probable Discharge, and the hydraulic characteristics of the dam. Discharge through the spillway section was computed as flow over a weir. Flow over the crest of the dam embankment was calculated by the weir discharge equation. Immediately downstream of the spillway crest the training walls bend to the left as they close from a 33 foot width to a 9 foot wide opening at the stone arch bridge. The spillway crest hydraulics do not appear to be affected by the turn and downstream construction as the top of the roadway is about 3.5 feet below the spillway crest. The roadway wouuld be overtopped before the tailwater would submerge the spillway crest. However, the overtopping of the roadway bridge will endanger the dam embankment by the potential of a washout of the roadway and the dam embankment. Under high flows the bend formed by the training walls will create a large amount of turbulence in the area immediately downstream of the spillway crest thus placing additional forces on the training walls.

The routing was started with the water surface at the crest of the spillway. It was assumed that the flashboards were not in place. The routed test flood outflow was determined to be approximately 1,860 cfs. As the maximum capacity of the spillway is approximately 700 cfs (about 38 percent of the routed test flood outflow) the dam will be overtopped by 0.5 feet.

f. Dam Failure Analysis. The impact of failure of the dam was assessed using the "Rule of Thumb" Guidance for Estimating Downstream Dam Failure Hydrographs prepared by the Corps of Engineers. The breach discharge was estimated with the water surface at the crest of the dam and a breach width equal to 40 percent of the mid-height length of the dam. The downstream hydrograph is a sum of the breach discharge and the maximum spillway discharge. Prior to the breach of dam the downstream river stage would be about 5 feet with the spillway at a full capacity discharge of 700 cfs. Breach of dam would result in an additional 71,400 cfs for a total of 72,100 cfs. The downstream stage was estimated in two reaches. One reach is between the Dam and the Reservoir Road crossing of Camp Brook 3,000 feet downstream. The second reach is from Reservoir Road to Storrs Road 2,000 feet downstream. The average breach flood stage through the reaches is about 20 feet. Between the dam and Reservoir Road a gravel road parallels the stream channel. The road is 4 to 5 feet above the streambed and would probably be

inundated by the river stage prior to the breach of dam. The breach flood wave would probably wash out this road. There are no dwellings in this reach. The Reservoir Road bridge has an 8 foot by 8 foot opening and is set 12 feet above the streambed. At the upstream end of Storrs Pond there is a camp ground which is set about 6 feet above the stream channel. The campground has recreational facilities including tennis courts and a pavilion for cookouts. Other than the campground there are no other dwellings or structures around Storrs Pond. All of the above will be totally inundated by the flood wave. Storrs Pond Dam is located about 3,000 feet downstream of the campground. If the level of Storrs Pond was at the spillway crest, the Storrs Pond Dam would be overtopped as the 240 acre-feet of available storage would be quickly filled. The breach wave at the head of Storrs Pond has a discharge of about 53,500 cfs.

SECTION 6
STRUCTURAL STABILITY

6.1 Evaluation of Structural Stability

a. Visual Observation. The visual inspection of Lower Reservoir Dam did not reveal any immedaite stability problems. The inspection revealed deterioration of the spillway structure, which if left unattended could lead to failure of the masonry training walls and significant erosion of the embankment during periods of high flow.

b. Design and Construction Data. Design drawings dated August 1954 exist which delineate the design for raising an existing dam at the site.

c. Operating Records. No operating records were made available.

d. Post-Construction Changes. There is no record of changes since the raising of the original dam.

The drawings indicate that the earlier dam was an embankment dam and that the addition raised the old dam 5 feet by placing an impervious fill directly on the earlier embankment. The new embankment incorporated a gravel toe section.

e. Seismic Stability. The dam is located in Seismic Zone 2, and in accordance with the recommended Phase I guidelines, does not warrant seismic analysis.

SECTION 7
ASSESSMENT, RECOMMENDATIONS AND REMEDIAL MEASURES

7.1 Dam Assessment

a. Condition. The visual inspection of Lower Reservoir Dam indicates that the dam is in poor condition. The inspection revealed the following:

(1) Caving and erosion of the embankment immediately behind the masonry section of the right training wall.

(2) The original stone masonry portions of the spillway still in place have undergone significant movement and the stone mortar has cracked.

(3) A stone arch bridge immediately downstream of the spillway has undergone movement and cracked through the arch.

(4) Leaks were noted at the junction of the toe of the spillway weir and spillway apron slab and at the floor of the channel under the stone arch bridge.

(5) Reinforcing steel has been exposed through a crack in the upstream right wingwall of the spillway.

(6) The spillway channel downstream has many trees along the banks and a fallen tree in the channel.

(7) There is no means of removing flashboards during high water without exposing personel to hazardous conditions.

The hydraulic analysis reveals that the spillway cannot pass the routed test flood without overtopping the dam.

b. Adequacy of Information. The lack of in-depth engineering data did not allow for a definitive review. Therefore, the adequacy of this dam could not be assessed from the standpoint of reviewing design and construction data but is based primarily on visual inspection, past performance history and sound engineering judgment.

c. Urgency. This dam is in generally poor condition. The recommendations and remedial measures described in Sections 7.2 and 7.3 should be accomplished within 1 year after receipt of this Phase I Inspection Report by the owner.

d. Necessity of Additional Investigation. No additional investigation is needed to complete the Phase I inspection.

7.2 Recommendations

The owner should engage a qualified, registered professional engineer to thoroughly investigate the spillway structure and arch bridge. The investigation should include but not be limited to:

(a) Alignment of the spillway structure should be re-evaluated with the intention of preventing overtopping and erosion behind the stone masonry walls at the downstream end of the spillway.

(b) In view of the fact that an ice jam has caused overtopping and erosion of the dam adjacent to the spillway, crest and downstream slope protection should be designed for the embankment adjacent to the spillway.

(c) Devise a means to allow removal of the flashboards during high water so that personnel will not be exposed to hazardous conditions during the removal operation.

The above recommendations should include remedial measures designed to overcome any problems revealed by the study. The remedial measures should be implemented by the owner.

7.3 Remedial Measures

(a) Remove any trees which overhang the spillway discharge channel, and remove any fallen trees in the channel.

(b) Establish a system such that the reservoir level can be monitored during periods of intense rainfall.

(c) Prepare a downstream warning system in the event of an emergency. This system should include a provision to close the campground at Storrs Pond when the reservoir reaches a critical level.

(d) A technical inspection program should be initiated and continued on a yearly basis.

7.4 Alternatives

There are no practical alternatives to the recommendations of Sections 7.2 and 7.3.

APPENDIX A

INSPECTION CHECKLIST

VISUAL INSPECTION CHECK LIST
PARTY ORGANIZATION

PROJECT Lower Dam
(Hanover)

DATE 10/26/79

TIME 9:30 AM

WEATHER Cloudy

W.S. ELEV. 705.2 U.S. - DN.S

PARTY:

1. D. LaGatta	GEI	6.	
2. S. Mazur	HNTB	7.	
3. R. Yarsites	HNTB	8.	
4. Carl Brink, Hanover Water Works Company		9.	
5.		10.	

	PROJECT FEATURE	INSPECTED BY	REMARKS
1.	Dam	Dan LaGatta	
2.	Spillway, Outlet and	Stan Mazur	
3.	Downstream Channel	Robert Yarsites	
4.			
5.			
6.			
7.			
8.			
9.			
10.			

PERIODIC INSPECTION CHECK LIST

PROJECT Lower Hanover Reservoir DATE 10/26/79

PROJECT FEATURE Dam Embankment NAME D. LaGatta

DISCIPLINE _____ NAME _____

AREA EVALUATED	CONDITION
DAM EMBANKMENT	
Crest Elevation	711.5
Current Pool Elevation	705.2
Maximum Impoundment to Date	709.4 estimated June 1973
Surface Cracks	None observed.
Pavement Condition	No pavement.
Movement or Settlement of Crest	None observed.
Lateral Movement	
Vertical Alignment	No misalignment observed.
Horizontal Alignment	
Condition at Abutment and at Concrete Structures	Erosion and caving of embankment behind spillway training wall.
Indications of Movement of Structural Items on Slopes	None.
Trespassing on Slopes	None.
Sloughing or Erosion of Slopes or Abutments	Remnants of overtopping damage behind left training wall of spillway.
Rock Slope Protection - Riprap Failures	None.
Unusual Movement or Cracking at or near Toes	Stone arch bridge over spillway has had major movements.
Unusual Embankment or Downstream Seepage	There is a seep in the floor of the spillway channel 65 ft d.s. of the weir. Clear water.
Piping or Boils	None observed.
Foundation Drainage Features	None.
Toe Drains	None.
Instrumentation System	None.
Vegetation	Excellent grass cover.

PERIODIC INSPECTION CHECK LIST

PROJECT Lower Dam DATE 10/26/79

PROJECT FEATURE Intake Channel/Structure NAME D. LaGatta

DISCIPLINE Geotechnical/Structural NAME S. Mazur

AREA EVALUATED	CONDITION
OUTLET WORKS - INTAKE CHANNEL AND INTAKE STRUCTURE	
a. Approach Channel	Approach channel is beneath reservoir surface.
Slope Conditions	
Bottom Conditions	
Rock Slides or Falls	
Log Boom	
Debris	
Condition of Concrete Lining	
Drains or Weep Holes	
b. Intake Structure	Intake structure - under water.
Condition of Concrete	
Stop Logs and Slots	

PERIODIC INSPECTION CHECK LIST

PROJECT Lower Dam DATE 10/26/79

PROJECT FEATURE Control Tower NAME S. Mazur

DISCIPLINE Structural/Hydraulic Engineers NAME R. Yarsites

AREA EVALUATED	CONDITION
OUTLET WORKS - CONTROL TOWER	
a. Concrete and Structural General Condition Condition of Joints Spalling Visible Reinforcing Rusting or Staining of Concrete Any Seepage or Efflorescence Joint Alignment Unusual Seepage or Leaks in Gate Chamber Cracks Rusting or Corrosion of Steel	Outlet works consist of a pond drain pipe and the water supply pipes. Gates and controls are located in gatehouse. Pipes and controls appear to be in good operational condition. Gatehouse consists of stone masonry substructure, brick superstructure (above water) and wooden roof-structure; good condition.
b. Mechanical and Electrical Air Vents Float Wells Crane Hoist Elevator Hydraulic System Service Gates Emergency Gates Lightning Protection System Emergency Power System Wiring and Lighting System	Mechanically (hand) operated gates - good condition. During inspection the control gates were not accessible for inspection.

PERIODIC INSPECTION CHECK LIST

PROJECT Lower Dam DATE 10/26/79

PROJECT FEATURE Outlet Works Conduit NAME S. Mazur

DISCIPLINE Structural/Hydraulic NAME R. Yarsites

AREA EVALUATED	CONDITION
OUTLET WORKS - TRANSITION AND CONDUIT	
General Condition of Concrete	The pond is drained by a 16 inch pipe as shown in Figure 1. The pipe is controlled by valve located in gate-house. It was reported that pond drain pipe is in good condition.
Rust or Staining on Concrete	
Spalling	
Erosion or Cavitation	
Cracking	
Alignment of Monoliths	
Alignment of Joints	
Numbering of Monoliths	

PERIODIC INSPECTION CHECK LIST

PROJECT Lower Dam DATE 10/26/79

PROJECT FEATURE Outlet Structure/Channel NAME R. Yarsites, S. Mazur

DISCIPLINE Hydraulic,Structural, Geotechnical NAME D. LaGatta

AREA EVALUATED	CONDITION
OUTLET WORKS - OUTLET STRUCTURE AND OUTLET CHANNEL	
General Condition of Concrete	Good condition. Outlet works consists of a 16 inch pipe with controls for a waste pipe.
Rust or Staining	
Spalling	Two outlet pipes to municipal water supply system not seen.
Erosion or Cavitation	
Visible Reinforcing	
Any Seepage or Efflorescence	
Condition at Joints	
Drain Holes	
Channel	
Loose Rock or Trees Overhanging Channel	None.
Condition of Discharge Channel	Good.

PERIODIC INSPECTION CHECK LIST

PROJECT Lower Dam DATE 10/26/79

PROJECT FEATURE Outlet Works-Spillway NAME D. LaGatta

DISCIPLINE Geotechnical, Hydraulic, Structural NAME R. Yarsites, S. Mazur

AREA EVALUATED	CONDITION
OUTLET WORKS - SPILLWAY WEIR, APPROACH AND DISCHARGE CHANNELS	
a. Approach Channel	Spillway structure in embankment approach channel beneath reservoir level.
General Condition	
Loose Rock Overhanding Channel	
Trees Overhanging Channel	
Floor of Approach Channel	
b. Weir and Training Walls	
General Condition of Concrete	Good condition. Considerable deterioration of left training wall. (Cracks)
Rust or Staining	None.
Spalling	Right wing, visible reinforcing.
Any Visible Reinforcing	Seepage at spillway channel slab.
Any Seepage or Efflorescence	None.
Drain Holes	
c. Discharge Channel	
General Channel	Cracks in training wall and stone arch buldge over discharge channel indicates there has been movement of structures along channel between weir and d.s. toe.
Loose Rock Overhanging Channel	
Trees Overhanging Channel	Dischage channel below embankment has many trees which should be removed.
Floor of Channel	
Other Obstructions	

PERIODIC INSPECTION CHECK LIST

PROJECT Lower Dam DATE 10/26/79

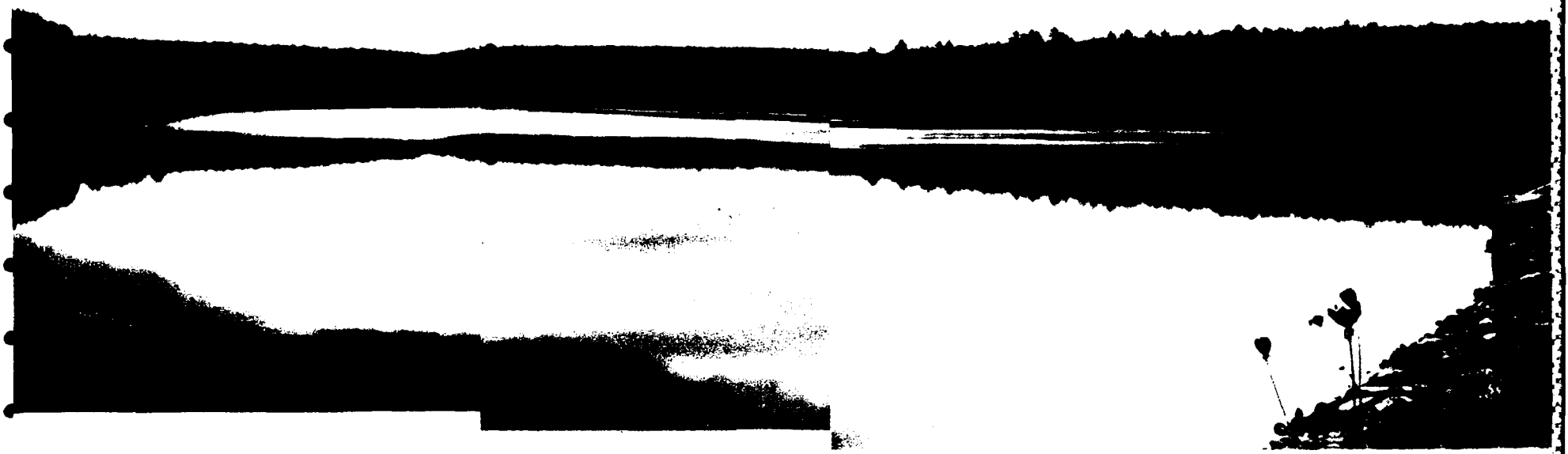
PROJECT FEATURE Service Deck NAME S. Mazur

DISCIPLINE Structural NAME

AREA EVALUATED	CONDITION
OUTLET WORKS - SERVICE BRIDGE	
a. Super Structure	Service deck to gatehouse consists of wood deck supported on steel beams; service deck appeared to be in good condition.
Bearings	
Anchor Bolts	
Bridge Seat	
Longitudinal Members	
Under Side of Deck	
Secondary Bracing	
Deck	
Drainage System	
Railings	
Expansion Joints	
Paint	
b. Abutment & Piers	
General Condition of Concrete	
Alignment of Abutment	
Approach to Bridge	
Condition of Seat & Backwall	

PHOTO NO. 2 - Crest of dam as seen from the left abutment.

PHOTO NO. 3 - Upstream slope of the dam as seen from the left abutment.



C-1

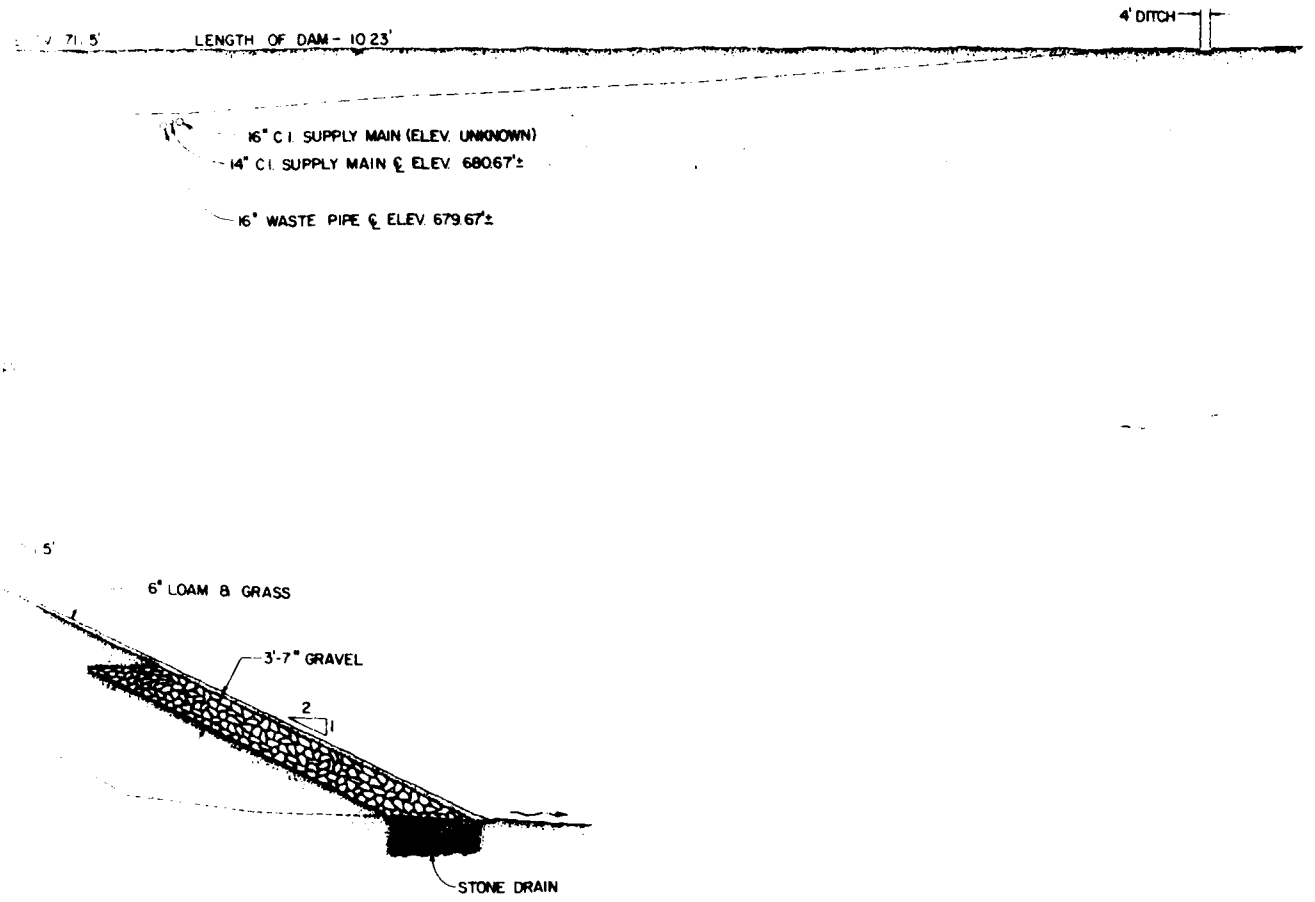
PHOTO NO. 1 - Panoramic view of reservoir from right end of dam.

APPENDIX C

PHOTOGRAPHS

FOR LOCATION OF PHOTOS, SEE FIGURE 1
LOCATED IN APPENDIX B

REPRODUCED AT GOVERNMENT EXPENSE



1. THE INFORMATION SHOWN ON THESE DRAWINGS IS BASED ON THE ORIGINAL CONSTRUCTION PLANS AND VISUAL OBSERVATIONS MADE DURING THE FIELD INSPECTION. DIMENSIONS OR MATERIALS INDICATED ON THESE DRAWINGS WHICH WERE BELOW GRADE OR WATER DURING THE TIME OF INSPECTION WERE NOT VERIFIED.

2. THE ELEVATIONS SHOWN IS N.G.V.D. 1929

[illegible] BOSTON, MASSACHUSETTS	US ARMY ENGINEER DIV. NEW ENGLAND [illegible] OF ENGINEERS WALTHAM, MASS.

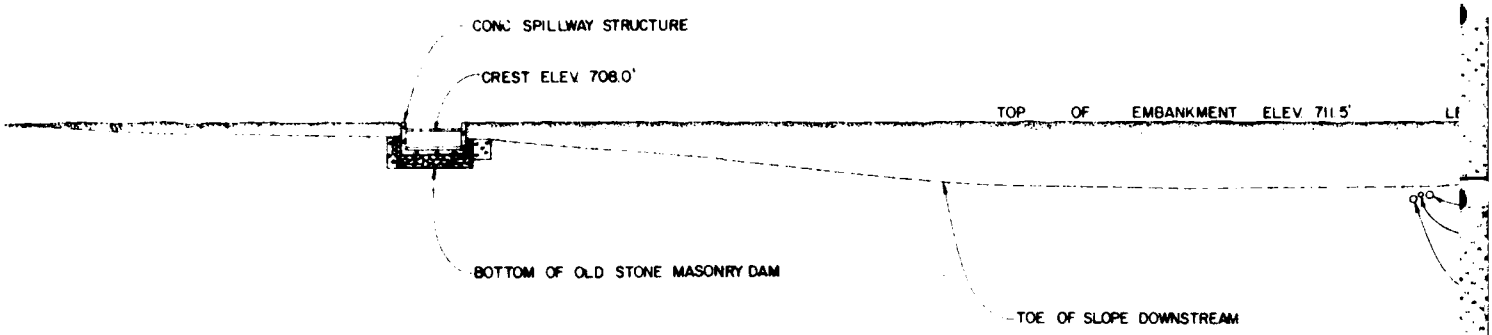
NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS

LOWER RESERVOIR DAM

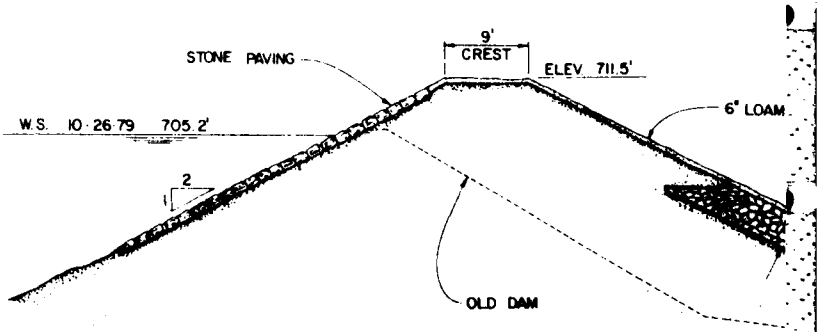
CAMP BROOK — HANOVER N.H.

Figure 2 of 2

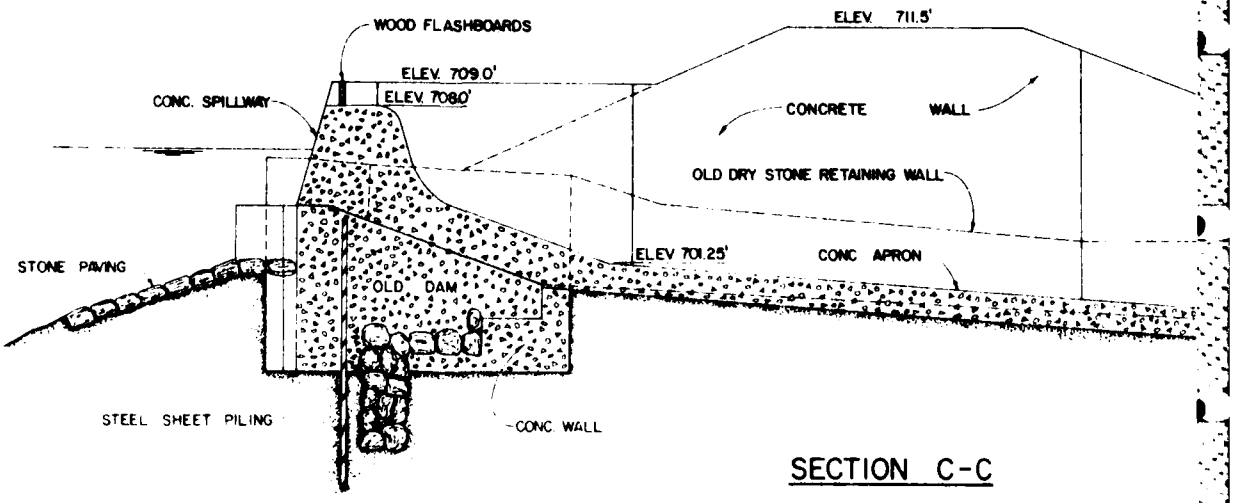
REPRODUCED AT GOVERNMENT EXPENSE



SECTION A-A



SECTION B-B

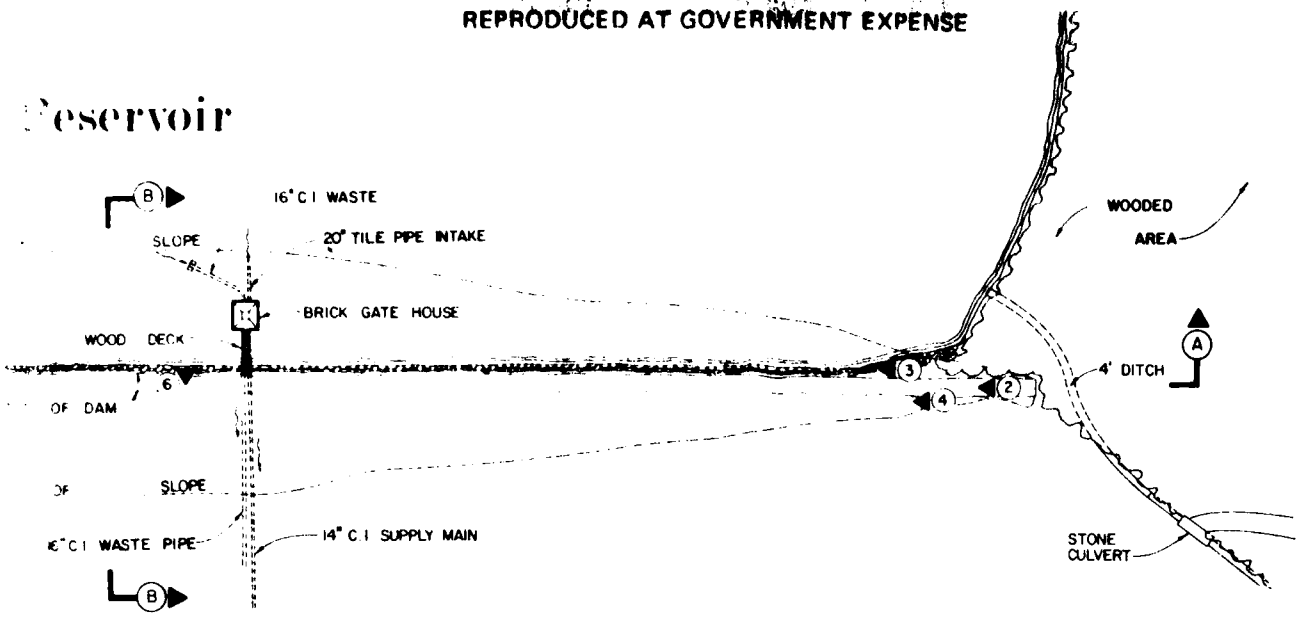


SECTION C-C

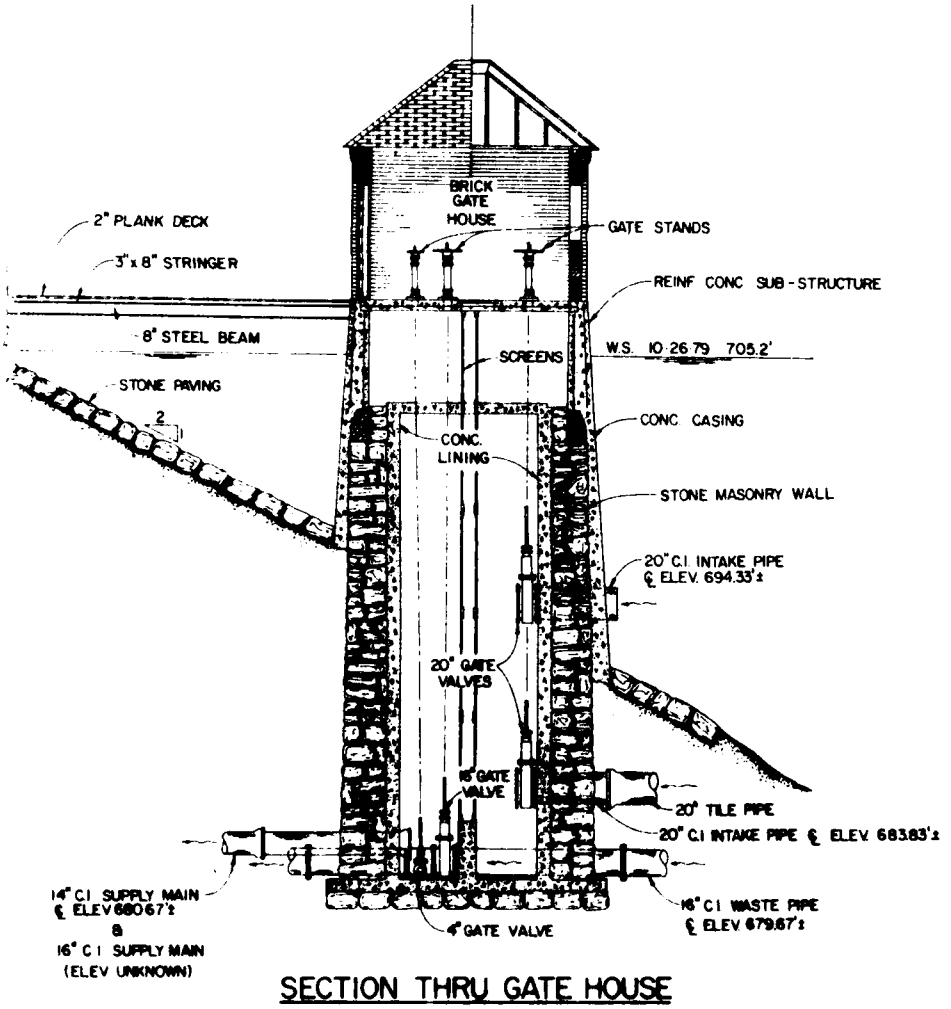
1/12

REPRODUCED AT GOVERNMENT EXPENSE

Reservoir



REVIEW PLAN



SECTION THRU GATE HOUSE

▲ (2) INDICATES PHOTO LOCATION & DIRECTION

1 THE INFORMATION SHOWN ON THESE DRAWINGS IS BASED ON THE ORIGINAL CONSTRUCTION PLANS AND VISUAL OBSERVATIONS MADE DURING THE FIELD INSPECTION. DIMENSIONS OR MATERIALS INDICATED ON THESE DRAWINGS WHICH WERE BELOW GRADE OR WATER DURING THE TIME OF INSPECTION WERE NOT VERIFIED.

2 THE ELEVATIONS SHOWN IS N.G.V.D. 1929

[illegible]	U.S. ARMY ENGINEER DIV. NEW ENGLAND [illegible]

NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS

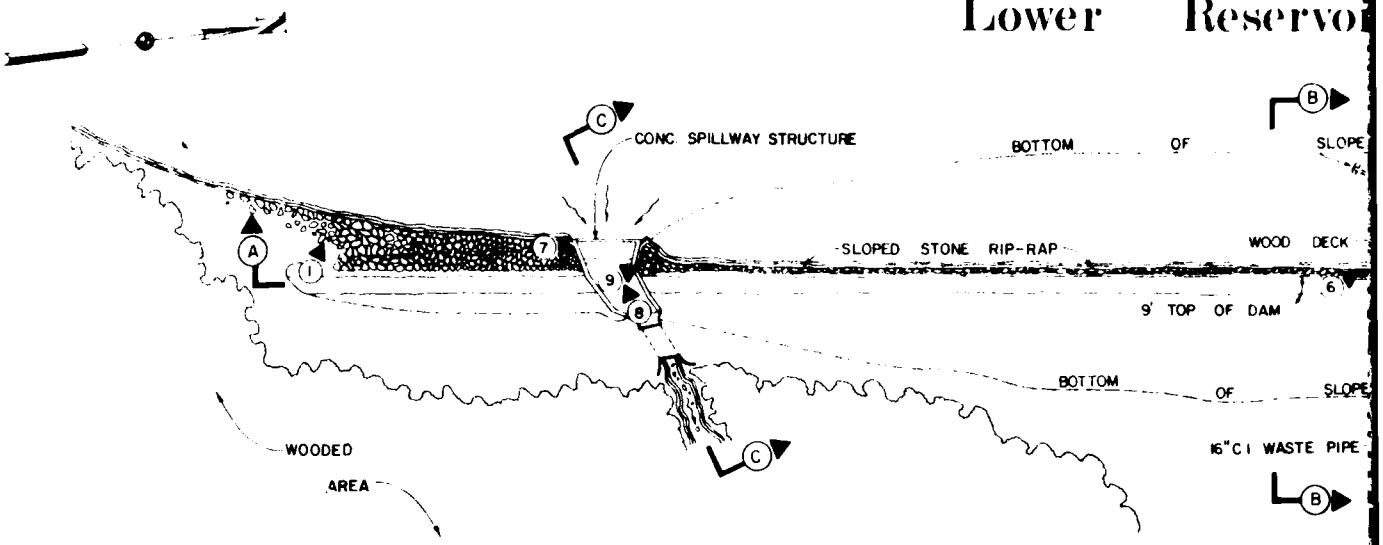
LOWER RESERVOIR DAM

CAMP BROOK — HANOVER N.H.

Figure 1 of 2

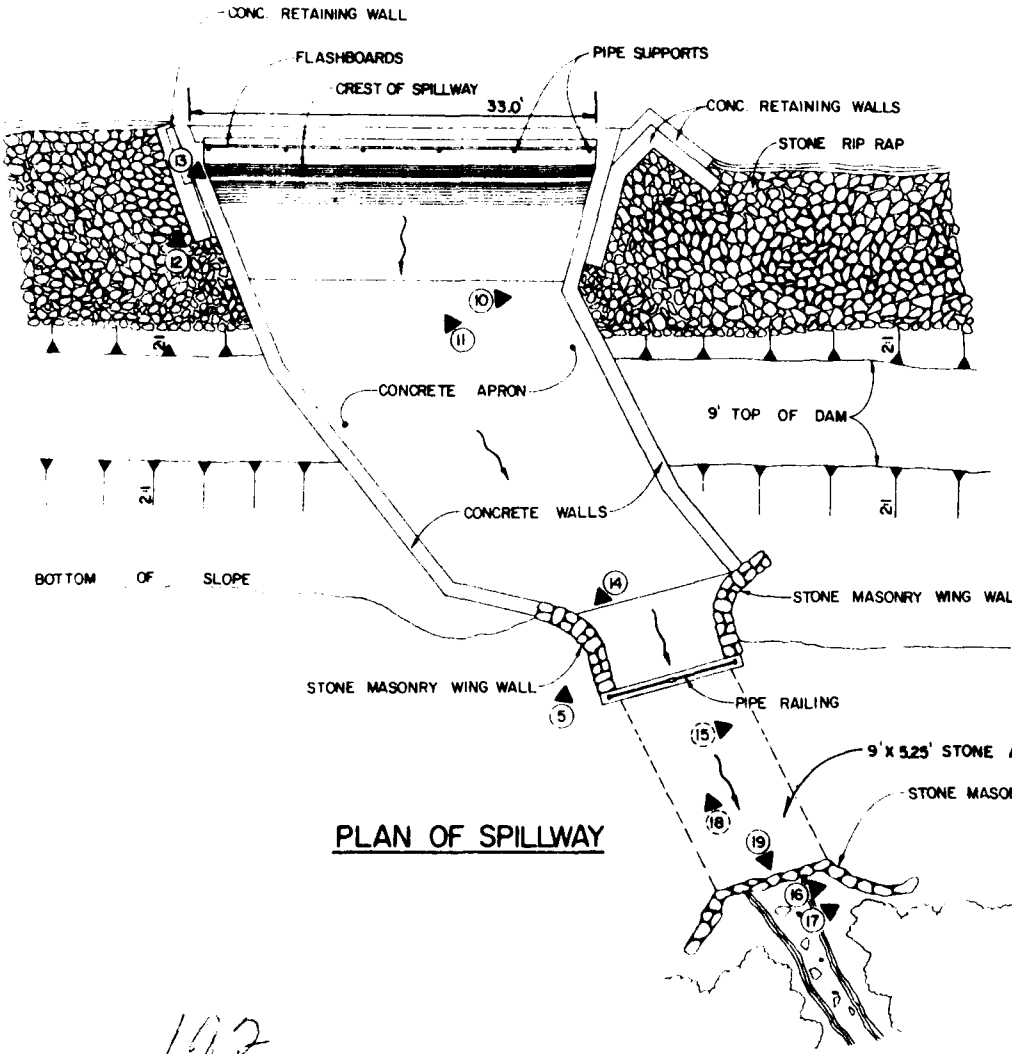
REPRODUCED AT GOVERNMENT EXPENSE

Lower Reservo

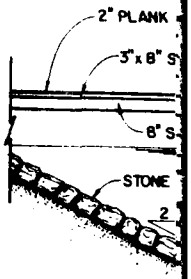


NOTE PHOTO 20 TAKEN 500' DOWNSTREAM
PHOTO 21 TAKEN 3000' DOWNSTREAM

OVERVIEW PLAN



PLAN OF SPILLWAY



14" C.I. SUPPLY M
℄ ELEV 680.67'±
&
16" C.I. SUPPLY
(ELEV UNKNOW

112

B-4

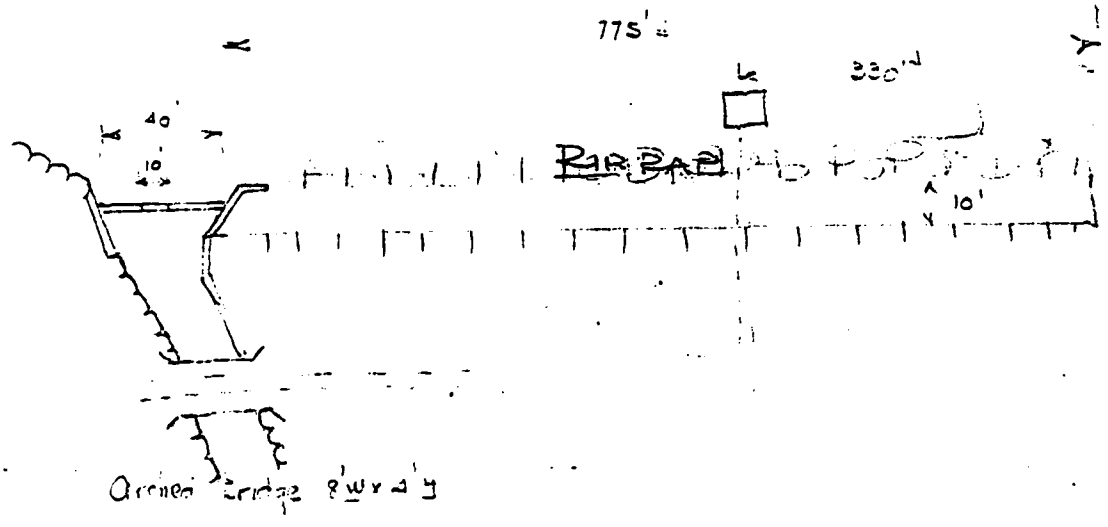
3722

PSHIRE PROJECT ..... FILE .....

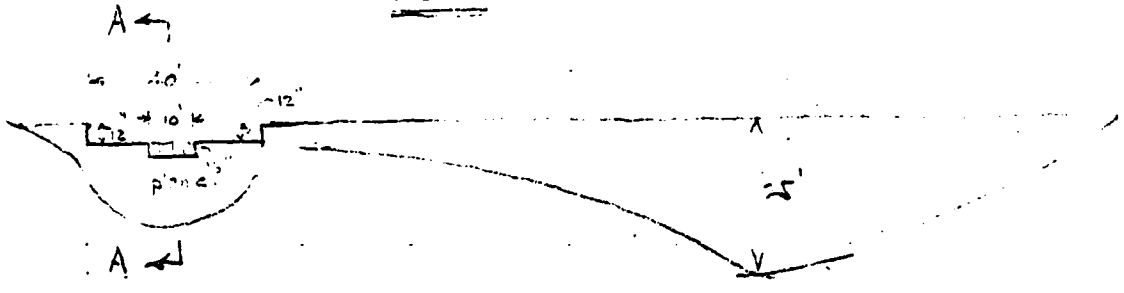
SOURCES SUBJECT HANOVER RESERVOIR - HANOVER ACC. 100.05

D LOWER RESERVOIR

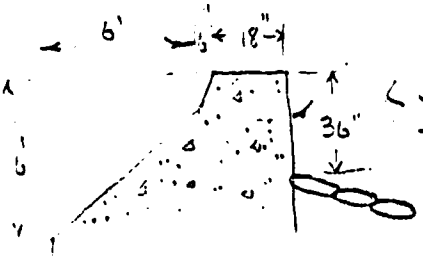
N H. COMPUTER ..... CHECKER ..... CONT. FROM ACC ..... CONT. ON ACC ..... SUMMARY ON ACC ..... DATE 9/27/57



PLAN.



PROFILE



Top cracked in places

SEC. 1-A.

B-3

NEW HAMPSHIRE WATER RESOURCES BOARD

INVENTORY OF DAMS AND WATER POWER DEVELOPMENTS

DAM

BASIN Connecticut   No. 5   106.05
RIVER Camp Brook   MILES FROM MOUTH ____ D.A.SQ.MI 1.91
TOWN Hanover   OWNER Hanover Water Works, Fred F. Parker Supt.
LOCAL NAME OF DAM Lower Reservoir
BUILT ____ DESCRIPTION Earth fill [illegible]
spillway

POND AREA-ACRES 28.64 DRAWDOWN FT. ____ POND CAPACITY-ACRE FT. ____
HEIGHT-TOP TO BED OF STREAM-FT. 25 MAX. ____ MIN. ____
OVERALL LENGTH OF DAM-FT. 2[illegible] MAX.FLOOD HEIGHT ABOVE CREST-FT. ____
PERMANENT CREST ELEV.U.S.G.S. 609 LOCAL GAGE ____
TAILWATER ELEV.U.S.G.S. ____ LOCAL GAGE ____
SPILLWAY LENGTHS-FT. 30' high [illegible] low FREEBOARD-FT. 1.0 high 1.5 low
FLASHBOARDS-TYPE, HEIGHT ABOVE CREST ____
WASTE GATES-NO. WIDTH MAX.OPENING DEPTH SILL BELOW CREST

REMARKS Condition good. top of spillway [illegible]
36 [illegible] Camp Brook Connecticut [illegible]

POWER DEVELOPMENT

UNITS NO.	RATED HP	HEAD FEET	C.F.S. FULL GATE	KW	MAKES

USE Water Supply for Hanover

REMARKS [illegible] on P.S.C. map listed by Selectmen. Water Works Supt was out of town. Mr Holmgren + Claude Smith of P.S.C. inspected water supply dams.

DATE 9/7/37 R.C.H.

SPILLWAY: Length: AD Freeboard: 2.5' B-2

SEEPAGE: Location, estimated quantity, etc.

None

Changes Since Construction or Last Inspection:

Tail Water Conditions:

Overall Condition of Dam: Good

Contact With Owner: No

Date of Inspection: 23 May 77 Suggested Reinspection Date 1930

Class of Dam: Menace B

Signature S Barnett

Date

Note: Give Sizing, Condition and detailed description for each item, if applicable,

B-1

NEW HAMPSHIRE WATER RESOURCES BOARD

INSPECTION REPORT

Town: ~~Hanover~~ Hanover Dam Number: 103.06

Name of Dam, Stream and/or Water Body: Lower Res.

Owner: Hanover Water Works Co. Telephone Number:

Mailing Address: Hanover

Max. Height of Dam: 25' Pond Area: Length of Dam: 900'

FOUNDATION: Earth

OUTLET WORKS: 40' Concrete O.G. Spillway with 12" Flashboards
2.5' Freeboard with Flashboards on

ABUTMENTS: Concrete in good condition

EMBANKMENT: Earth Embankment with 2:1 Slopes. Stone Paved on upstream side - Well vegetated on top and downstream slope. 10' wide top No Trees

Note: Give Sizing, Condition and detailed description for each item, if applicable.

PAST INSPECTION REPORTS

AVAILABLE ENGINEERING DATA

1. A set of drawings (3 sheets), dated August 1954, showing the existing dam and the proposed modifictions. The plans are available at the New Hampshire Water Resources Board, 37 Pleasant Street, Concord, New Hampshire.

APPENDIX B

ENGINEERING DATA

1. LIST OF DESIGN, CONSTRUCTION AND MAINTENANCE RECORDS
2. PAST INSPECTION REPORTS
3. PLAN AND DETAILS

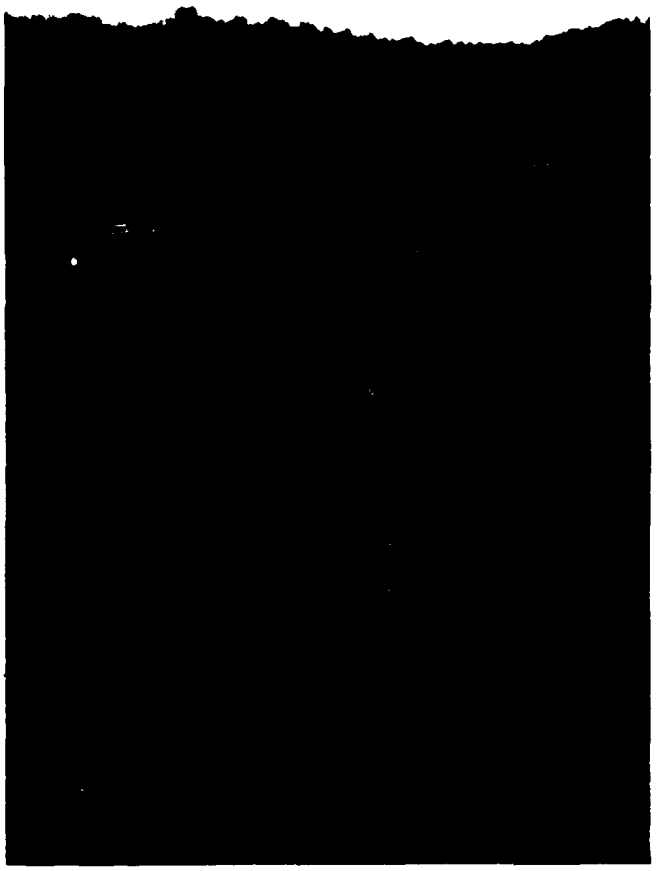


PHOTO NO. 4 - Downstream slope as seen from the left abutment.

PHOTO NO. 5 - Caving and erosion immediately behind the masonry section of the right training wall.

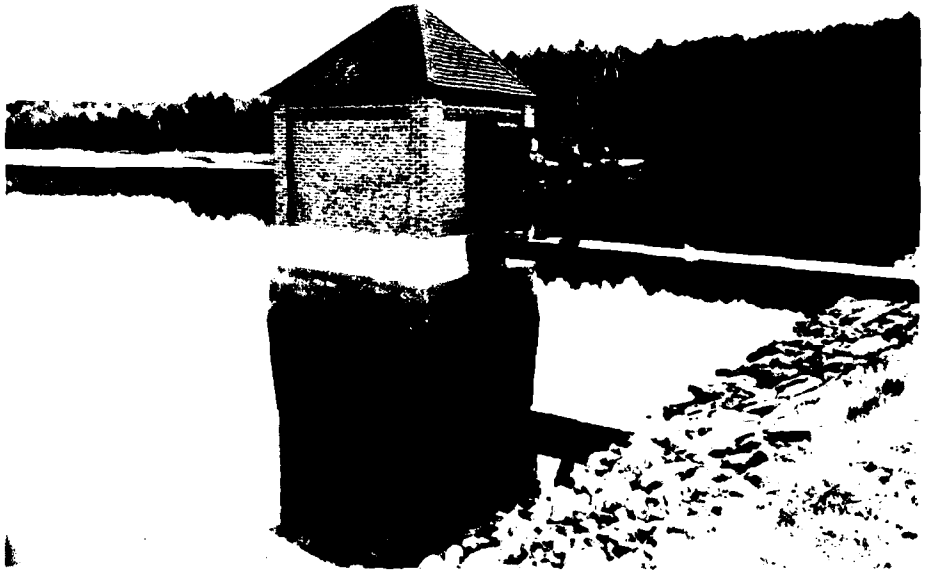


PHOTO NO. 6 - Gatehouse as seen from the crest of the dam.

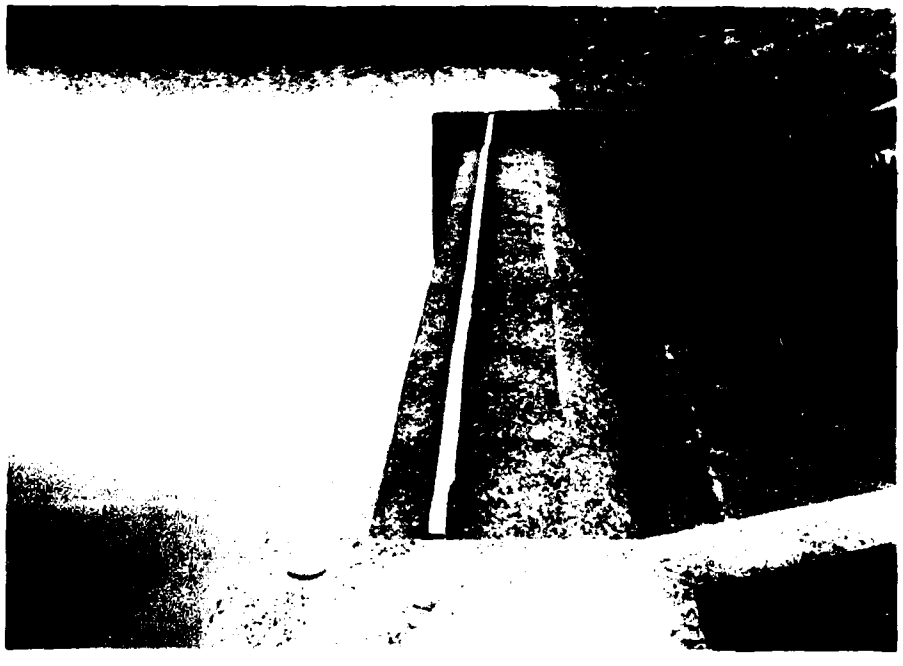


PHOTO NO. 7 - Weir crest and flashboards of the spillway.

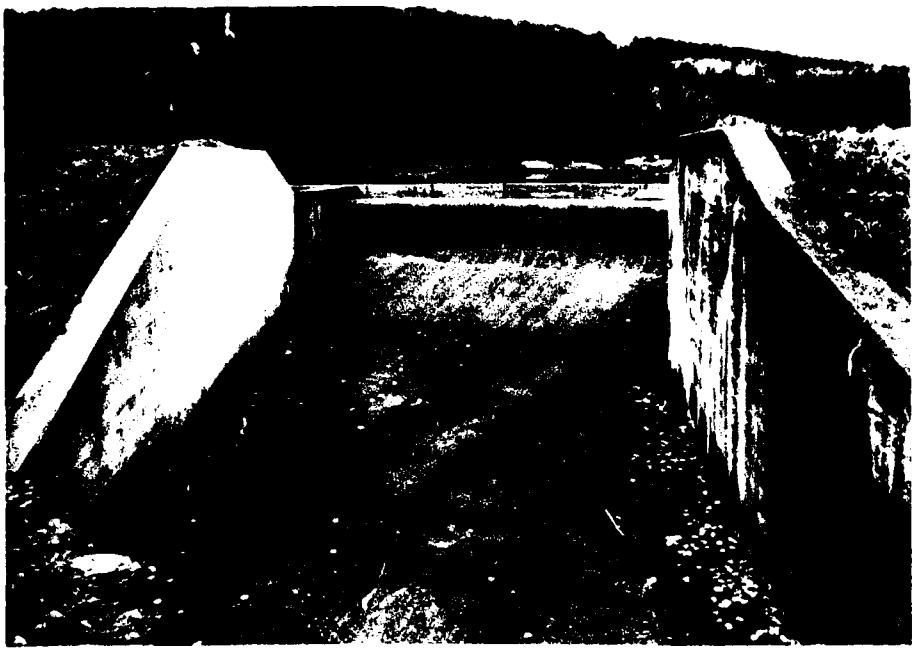


PHOTO NO. 8 - View of the downstream side of the spillway weir crest.

PHOTO NO. 9 - Cracking on the left training wall of the spillway.

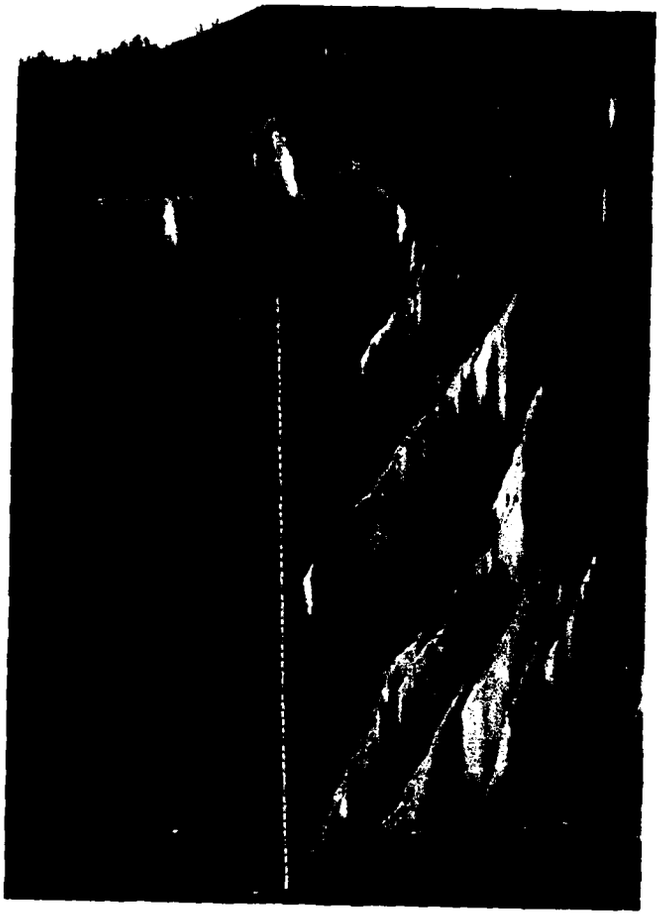


PHOTO NO. 10 - Another view of the cracking on the left training wall.

PHOTO NO. 11 - View of seepage at the joint of the downstream side of the weir and the spillway apron slab.

PHOTO NO. 12 - Upstream right side of the spillway training wall. Note large crack.

PHOTO NO. 13 - Masonry bridge at downstream end of spillway section.

PHOTO NO. 14 - Crack in masonry section of section of right training wall of spillway.

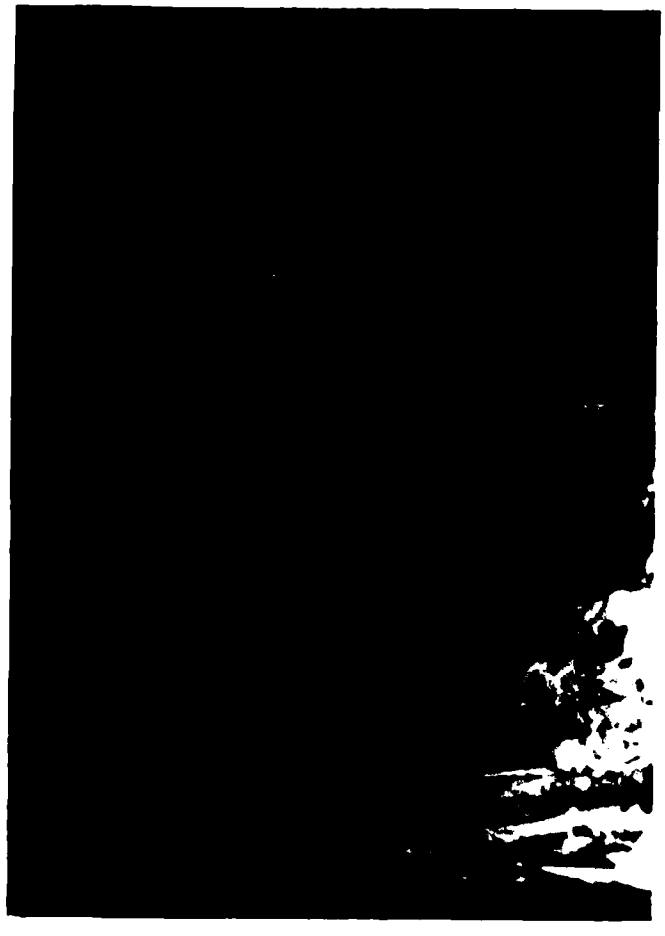


PHOTO NO. 15 - Crack on inside of masonry bridge arch.

PHOTO NO. 16 - Displacement of masonry training wall downstream and adjacent to left abutment of bridge.

PHOTO NO. 17 - Tilling of masonry wingwall just downstream of bridge abutment. Note wall is "leaning' on tree.

PHOTO NO. 18 - Leakage from beneath floor of arch bridge. Leak is 65 feet downstream of spillway weir.

PHOTO NO. 19 - Spillway channel downstream of embankment.

PHOTO NO. 20 - Roadway and outlet channel about 500 feet downstream of dam. The channel is in low area to the right of the photo.

PHOTO NO. 21 - Reservoir road bridge over Camp Brook located about 3000 feet downstream of the dam.

APPENDIX D

HYDROLOGIC AND HYDRAULIC COMPUTATIONS

HNTB EDWARD NEEDLES TAMMEN & BERGENDOFF	Made by RY	Date 11/12/79	Job No. 5965-11-13
	Checked by HM	Date 20 Nov. 79	Sheet No. 1

LOWER RESERVOIR DAM

HYDRAULICS & HYDROLOGY

LOWER RESERVOIR DAM Located along Camp Brook 2mi upstream of the Connecticut River in Hanover, Grafton County, New Hampshire.

Classification: Size: Small
Hazard: Significant

Basic Data Da = 1.86 Sq mi
Max. Elev. 1280' MSL
Mountainous 200 ft/mi (channel and basin slope).
D.A. Upper Res .83 Sq mi
Reservoir Surface Area: 47 acres
Top of Dam, elev. 711.5' Storage - 823 acre-ft
Top of Flashboards 709' " 706 "
Crest Spillway 708' " 659 "
704.46' " 494 "

Dam: Earth
Length - 1023 ft.
Height - 33 ft.

Spillway - weir
Length 33'
w/ flashboards 1.0 ft high

Outlets 12" ϕ Pipe } w.s. intakes
16" ϕ Pipe }
16" ϕ pipe pond drain

NTB WARD NEEDLES TAMMEN & BERGENDOFF	Made by RY	Date 11/12/79	Job No. 5965-11-13
	Checked by HM	Date 20 NOV. 79	Sheet No. 2

Lower

Step 1 Calculation of Test Flood Inflow.

Classification : Size : small
hazard : significant

Hydrologic Evaluation Huddline Recommends

100 yr Frequency flood to ½ PMF for Test flood inflow

Use ½ PMF as size is on higher end of classification range. 823 acre-ft vs. a maximum of 1000 a-f and a height of 33 feet vs. a maximum of 40 ft.

Use mountainous curve as there is a steep tributary area. As drainage area is outside of the PMF guide curve envelope use the maximum PMF value of 3000 csm

Upper Reservoir has a tributary area .83 sq mi of the watershed with 1.03 sq mi directly tributary to Lower Reservoir

Test flood inflow to Upper Res

½ × 3000 × .83 = 1245 cfs

Routed test flood outflow - 780 cfs
see calculations at the end of this section pg 2-2 to 2-5

Test flood inflow direct to Lower Reservoir

½ × 3000 × 1.03 = 1545 cfs

Upper Reservoir Outflow	780 cfs
Inflow direct to Lower Res	1545 cfs

Total Inflow to Lower Reservoir 2325 cfs

INTB	Made by KV	Date 11/13/79	Job No. 5955-11-13
MARO NEEDLES TAMMEN & BERGENDOFF	Checked by HM	Date 20 Nov. 79	Sheet No. 3

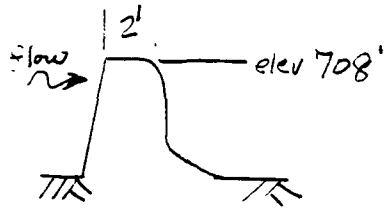
LOWER

Step 2 Calculation of Surcharge

Consider : No significant flow thru the water supply intakes or pond drain.

: No flashboards in place

Spillway Discharge weir $Q = CLH^{3/2}$



$L = 3.25$
$L = 33'$ across weir
Permanent crest elev. 708.0'

$Q = 3.25(33)H^{3/2} = 107.25H^{3/2}$

With flashboards $C = 3.44$ Discharge with water surface at top of dam
$Q = 3.44(33)(2.5)^{1.5} = 450$ cfs.

Discharge over dam Crest $Q = CLH^{3/2}$

$C = 3.08$

Crest elev 711.5

$L = 1023 - 33 = 990$ ft

$Q = 3.08(990)(H-3.5)^{1.5} = 3049.2(H-3.5)^{1.5}$

Stage - Discharge See fig 1

Elev	H	$Q_{spillway}$	Q_{Dam}	Total	
708	0	-	-	0 cfs	
709	1 ft	110 cfs		110	
710	2	300		300	
711	3	560		560	
711.5	3.5	700		700	
711.6	3.6	730	100 cfs	830	
711.8	3.8	790	500	1290	
712.0	4.0	860	1080	1940	D-3
712.2	4.2	920	1790	2710	

Step 3 Calculation of Surcharge Effect

Q_{P_1} = 2325 cfs RO = 9.5 inches

Storage above spillway crest vertical prism Tidersurface 47Ac.

Start routing with water surface at spillway crest.

$$Q_{P_2} = Q_{P_1} \times \left(1 - \frac{Stor_{in}}{9.5}\right)$$

$$Stor(in) = \frac{\text{Storage in AF} \times 12\ in/ft}{640\ \frac{acre}{mi^2} \times 1.86\ mi^2} = 0.0101 \text{ Stor A-F}$$

Routing Curve See fig 1

Flow	Storage	Stor(in)	Q_{P_2}
708	0		2325 cfs
709	47 acre-ft	.47 in	2210
710	94	.95	2090
711	141	1.42	1980
712	188	1.90	1860
713	235	2.37	1740

See fig 1 for outflow 1860 cfs

Stage 712.0 ft
0.50 ft above dam

Spillway 38% of Routed test flood outflow

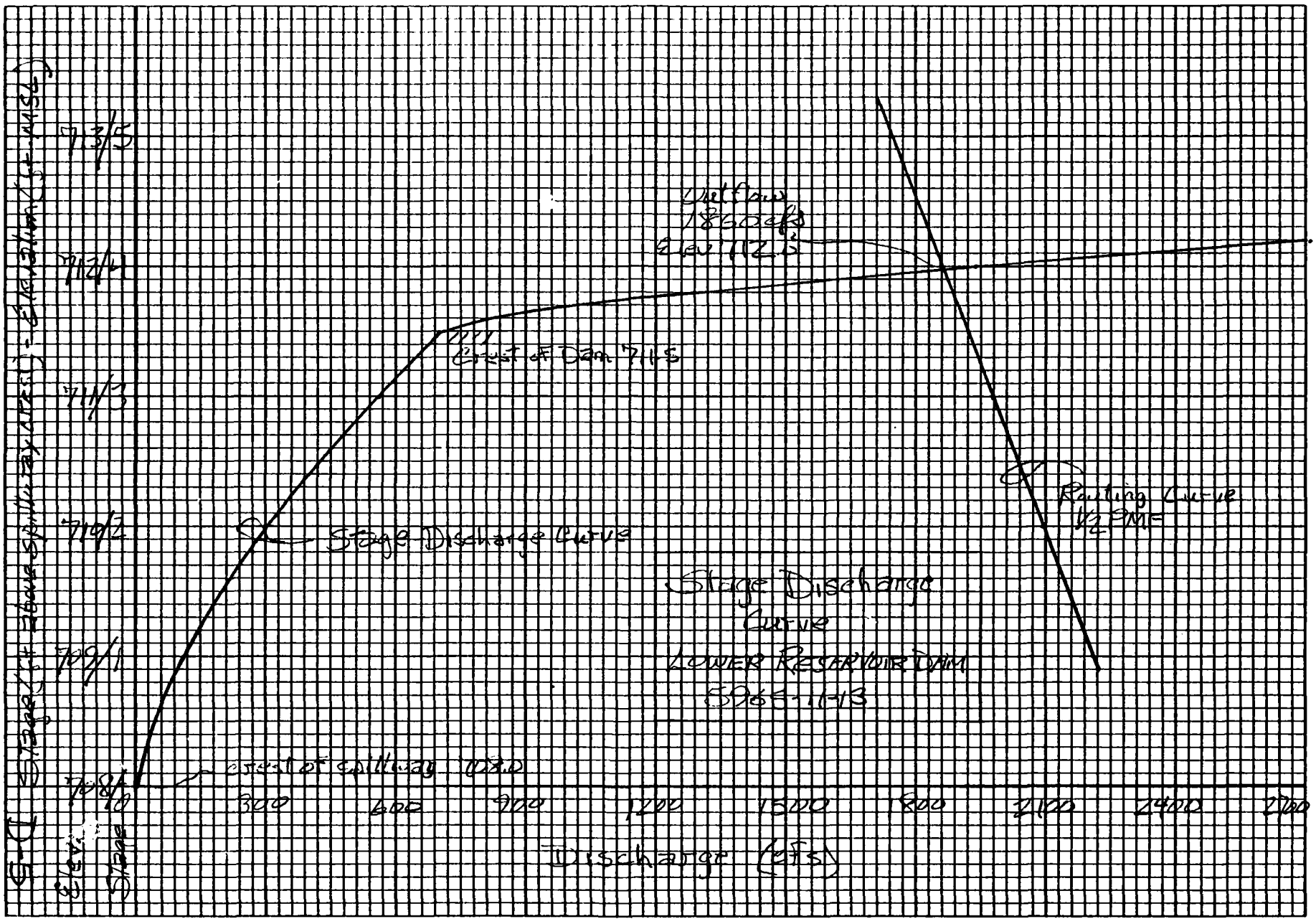

Elevation in Feet above Mean Sea Level (MSL)
713.5
713
712.5
712
711.5
711
710.5
710
Crest of Dam 711.5
Crest of Spillway 710.0
Stage Discharge Curve
Outflow
18 Inch Pipe
Elev 712.5
Rating Curve
1/2 Inch Orifice
Stage Discharge
Curve
LOWER RESERVOIR DAM
8966-11-13
300
600
900
1200
1500
1800
2100
2400
2700
Discharge (CFS)

FIGURE 7

HNTB HOWARD NEEDLES TAMMEN & BERGENDOFF	Made by RY	Date 11/13/79	Job No 5965-11-14
	Checked by HM	Date 20 Nov. 79	Sheet No. 2-2

For Upper Reservoir for Inflow to Lower Reservoir

Step 1 Calculation of Test Flood Inflow

Classification Size: Small
Hazard: Significant

Hydrologic Evaluation Guideline Recommends
100 yr. Frequency flood to ½ PMF

Use ½ PMF as size is on higher end of Classification range 730 acre-ft vs max of 1000 acre-ft
30 ft height max of 40 ft height

Use Mountainous Curve step tributary area
As size of basin is outside PMF curve envelope use maximum value of 3000 csm.

$$\text{Test Flood Inflow} = 3000 \text{ csm} \times \frac{1}{2} \times .83 \text{ mi}^2$$

$$= 1245 \text{ cfs.}$$

Total Runoff = ½ × 19 inch = 9.5 inches.

HNTB — HOWARD NEEDLES TAMMEN & BERGENDOFF

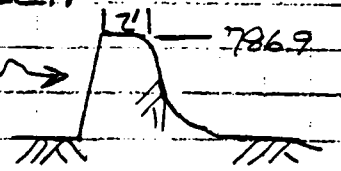
Made by	RY	Date	11/13/79	Job No.	5965-11-14
Checked by	HM	Date	20 NOV. 79	Sheet No.	2-3

For Upper Reservoir for Inflow to Lower Reservoir

Step 2 Calculation of Surcharge Effect

Consider: No Significant flow thru 2-10" ϕ outlet pipes.
No. Flashboards in place 1.4' high

Spillway discharge weir $Q = CLH^{3/2}$



$C = 3.25$ w/o Flash
$L = 25'$
Permanent crest El. 786.9' M.S.L.

$$Q = 3.25(25)H^{3/2} = 81.25H^{3/2}$$

Discharge over dam crest - $Q = CLH^{3/2}$ Crest El. 790.5 M.S.L.
$C = 3.08$
$L = 1340 - 25 = 1315$
$Q = 3.08(1315)(H-3.60)^{3/2} = 4050.2(H-3.6)^{3/2}$

See figure 1

Stage-Discharge

Elev	H	Qspillway	Qdam	Total
786.9	0	-		0
788.0	1.1 ft	94 cfs		94 cfs
789.0	2.1	250		250
790.0	3.1	440		440
790.5	3.6	550		550
790.6	3.7	580	130 cfs	710
790.7	3.8	600	360	960
790.8	3.9	630	660	1290

HNTB
HOWARD NEEDLES TAMMEN & BERGENDOFF

Made by	RY	Date	11/14/79	Job No.	5965-11-14
Checked by	HN	Date	20 Nov 79	Sheet No.	2-4

For Upper Reservoir for Inflow to Lower Reservoir

Step 3 Calculation of Surcharge Effect

$Qp_1 = 1245$ cfs

Storage above dam crest - vertical prism Lake Surface 7.7A

Start routing with water surface at the spillway crest

$$Qp_2 = Qp_1 \times \left(1 - \frac{Stor}{9.5}\right)$$

$$Stor_{(in)} = \frac{\text{Storage AF} \times 12\text{ in/ft}}{640\text{ ac/mi}^2 \times .83\text{ mi}^2} = \text{Storage}(.02259)$$

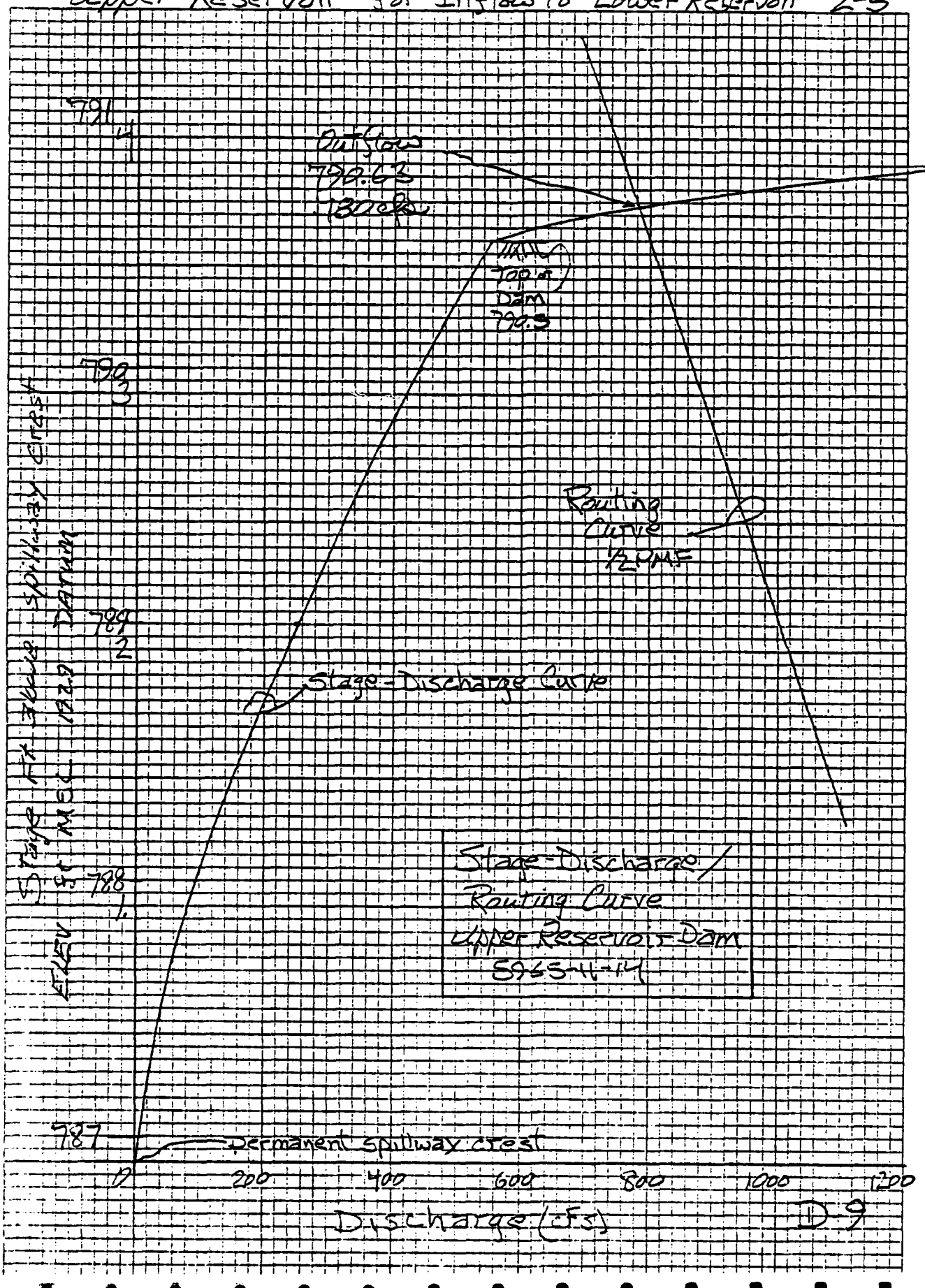
Elev	Storage	Stor(in)	Qp_2
786.9	0	0	1245 cfs
788.3	50	1.13	1100
789.3	95	2.15	960
790.3	141	3.19	830
791.3	187	4.22	690

See Figure 1 for Outflow 780 cfs

Stage 790.63 say 790.6 ft

Overtops Dam by .10 ft.

Upper Reservoir for Inflow to Lower Reservoir Z-5



HNTB HOWARD NEEDLES TAMMEN & BERGENDOFF	Made by RY	Date 11/14/79	Job No. 5965-11-13
	Checked by HH	Date 20 NOV 79	Sheet No. 5
For LOWER RESERVOIR			

DOWNSTREAM DAMAGE ASSESSMENT

Step 1 Reservoir Storage

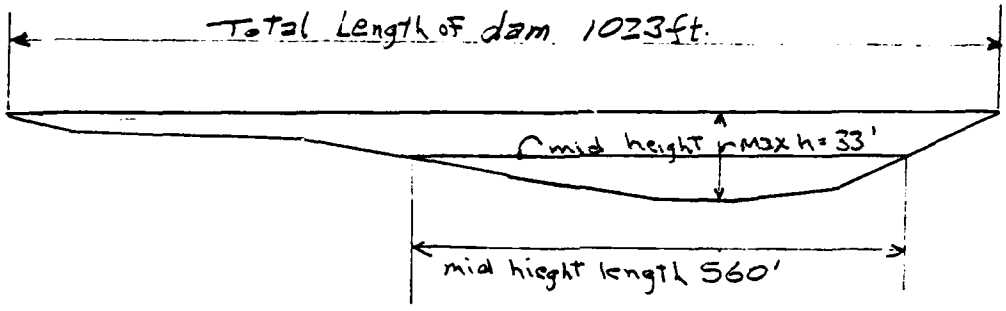
Top of dam elev 711.5 storage 823 acre-ft

Step 2 Breach Outflow

$$Q_{Breach} = 8/27 \sqrt{g}\, w_o y_o^{3/2}$$

w_o = 40% of dam length at mid height

y_o = maximum height streambed to top of dam

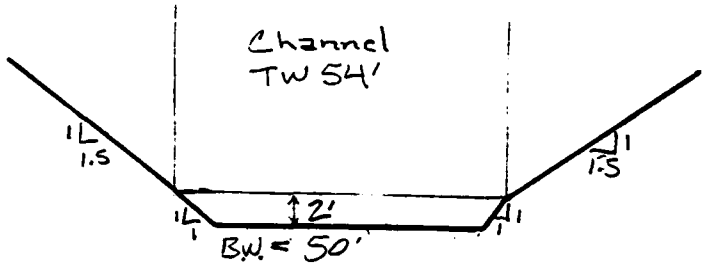


$$Q_{Breach} = 8/27 \sqrt{g}\,(40)(560)(33)^{3/2} = 71{,}400 \text{ cfs}$$

$Q_{spillway}$ 700 cfs

Total Breach wave = 72,100 cfs

Step 3 Stage - Discharge Curve - Reach-1



Channel Length 3000'
S = 0.0593 ft/ft
n channel = .05
n overbank = .08

See fig2 for plot

Stage (Feet)	Q (C.F.S.)
2	1140
10	18,590
15	38,320
20	64,740
22	77,214

Step 4 Reach Outflow Reach-1

$Q_{P_1} = 72{,}100$ cfs $L = 3000'$ $S = 823$ acre ft

Stage$_1$ = 21.1 ft area = 1700 ft^2

$V_1 = \frac{1700\ ft^2 \times 3000\ ft}{43560\ ft^2/acre} = 117$ acre ft $< \frac{S}{2} = 3$ Reach OK

$Q_{P_2} = 72{,}100\left(1 - \frac{117}{823}\right) = 61850$ cfs

Stage$_2$ 19.4 ft area$_2$ = 1500 ft^2

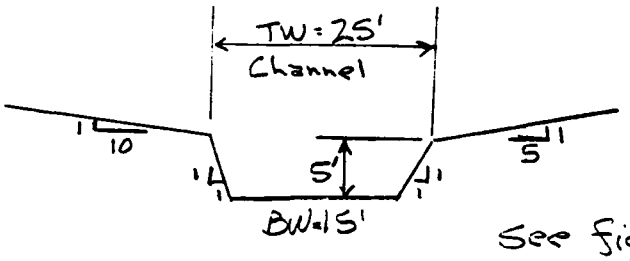
$V_2 = \frac{1500 \times 3000}{43560} = 103$ acre-ft

$V_{ave} = 110$ acre ft

$Q_{P_2} = 72{,}100\left(1 - \frac{110}{823}\right) = 62{,}400$ cfs ✓

Stage 20.0 ft.

Step 3 Stage-Discharge Reach-2



Reach 2 - 2000'
S = .0510 ft/ft
η channel = .05
η overbank = .08

See fig 2 for plot

Stage	Discharge
5	1540 cfs
10	7360
15	21550
20	47660
22	62100

Step 4 Reach Outflow Reach 2

$Q_{P_1} = 62{,}400$ cfs

L = 2000'
S = 823 acre ft

Stage$_1$ = 22.1 ft Area$_1$ = 2708 ft^2

$$V_1 = \frac{2708 \text{ ft}^2 \times 2000 \text{ ft}}{43560 \text{ sq ft/ac}} = 124 \text{ acre ft}$$

$$Q_{P_2} = 62{,}400\left(1 - \frac{124}{823}\right) = 53000 \text{ cfs}$$

Stage$_2$ = 21.0 ft Area$_2$ = 2420 ft^2

$$V_1 = \frac{2420 \times 2000}{43560} = 111 \text{ acre ft}$$

V_{ave} = 117.8 acre

$$Q_{P_2} = 62{,}400\left(1 - \frac{117.8}{823}\right) = 53{,}470 \text{ cfs}$$

Stage$_2$ = 21.0 ft

HNTB HOWARD NEEDLES TAMMEN & BERGENDOFF	Made by RY	Date 11/13/79	Job No. 5965-11-13
	Checked by HN	Date 20 NOV 79	Sheet No. 8
For LOWER RES			

Lower Res Discharge to Storrs Pond 54/100 cfs

Surface Area Storrs Pond 34 acres

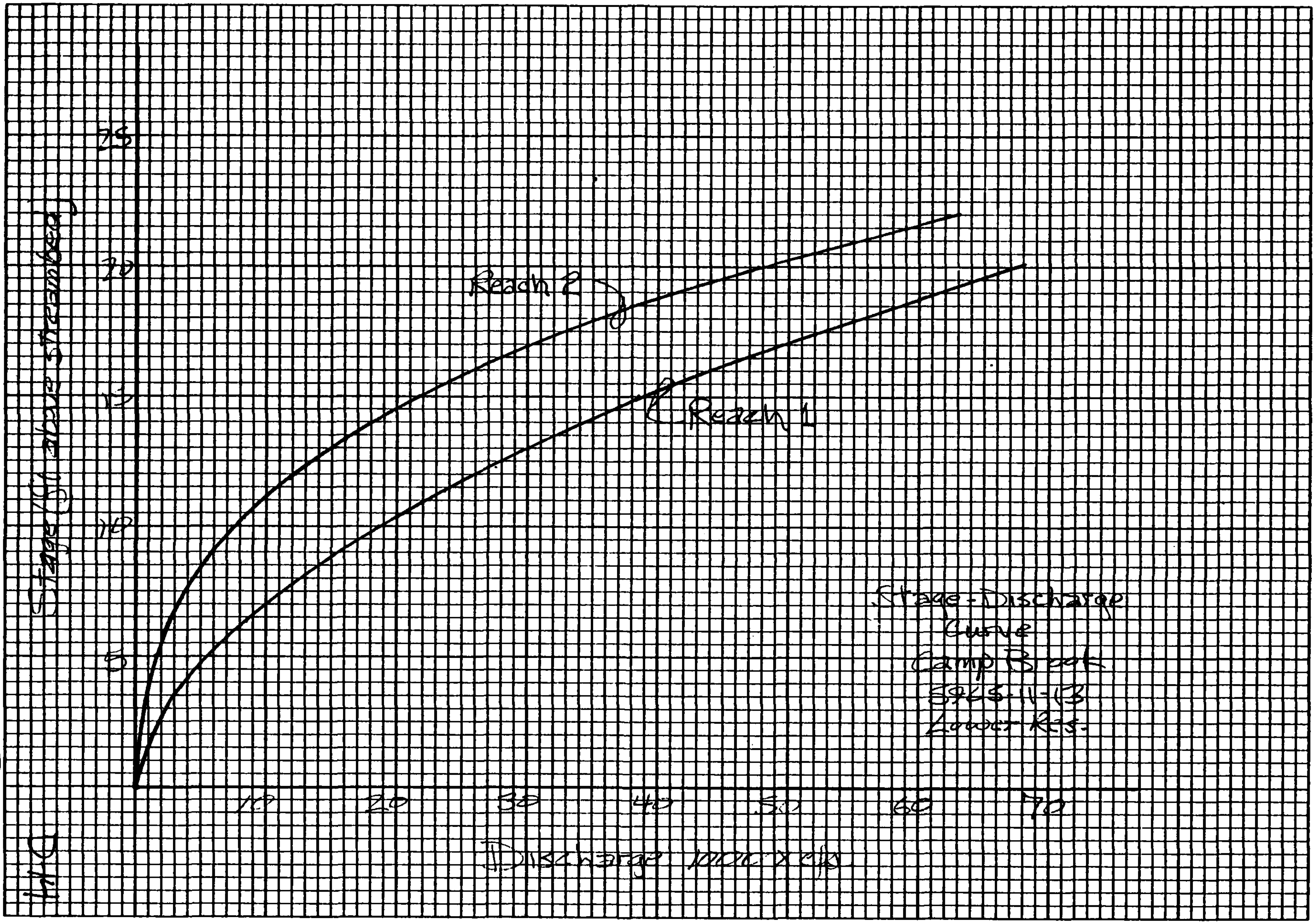
Top of dam 422.69

Spillway crest 415.64

7.05

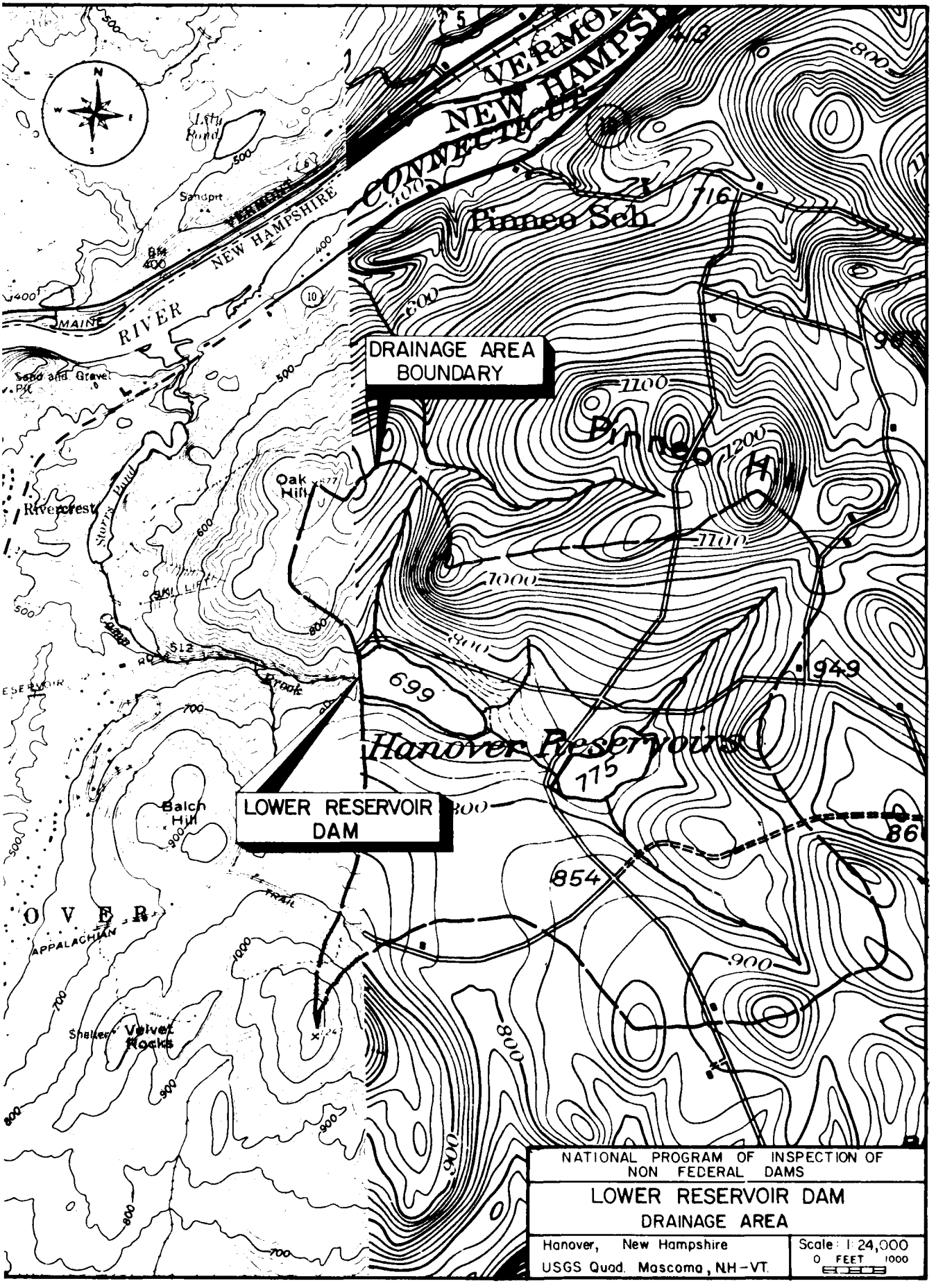
If water level is at the crest of the spillway at Storrs Pond Dam 7.05 x 34 = 240 acre ft of inflow + spillway discharge would be required to overtop dam

At an inflow rate of about 50,000 cfs it would take about 4 min for the Storrs pond dam to be overtopped.


Stage-Discharge
Curve
Camp Brook
Secs 11-13
Lower Res.
Reach 2
Reach 1
25
20
15
10
5
10
20
30
40
50
60
70
Discharge 1000 x cfs
Stage (ft above streambed)

D-14

FIGURE 2

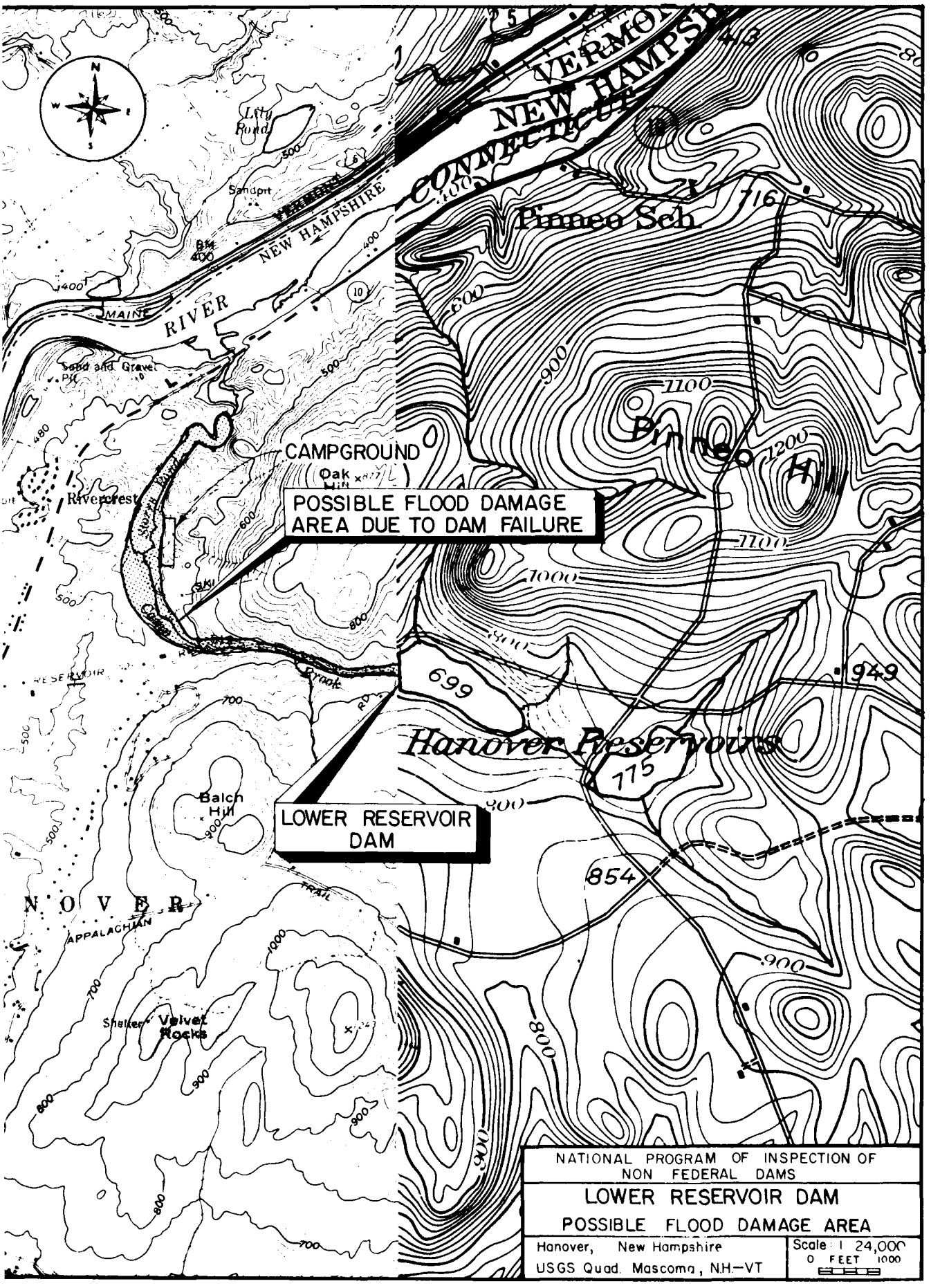


NATIONAL PROGRAM OF INSPECTION OF NON FEDERAL DAMS

LOWER RESERVOIR DAM
DRAINAGE AREA

Hanover, New Hampshire
USGS Quad. Mascoma, NH-VT.

Scale: 1:24,000
0 FEET 1000



NATIONAL PROGRAM OF INSPECTION OF NON FEDERAL DAMS

LOWER RESERVOIR DAM

POSSIBLE FLOOD DAMAGE AREA

Hanover, New Hampshire

USGS Quad. Mascoma, N.H.—VT

Scale 1 24,000

0 FEET 1000

APPENDIX E

INFORMATION AS CONTAINED IN THE NATIONAL INVENTORY OF DAMS

END

FILMED

8-85

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